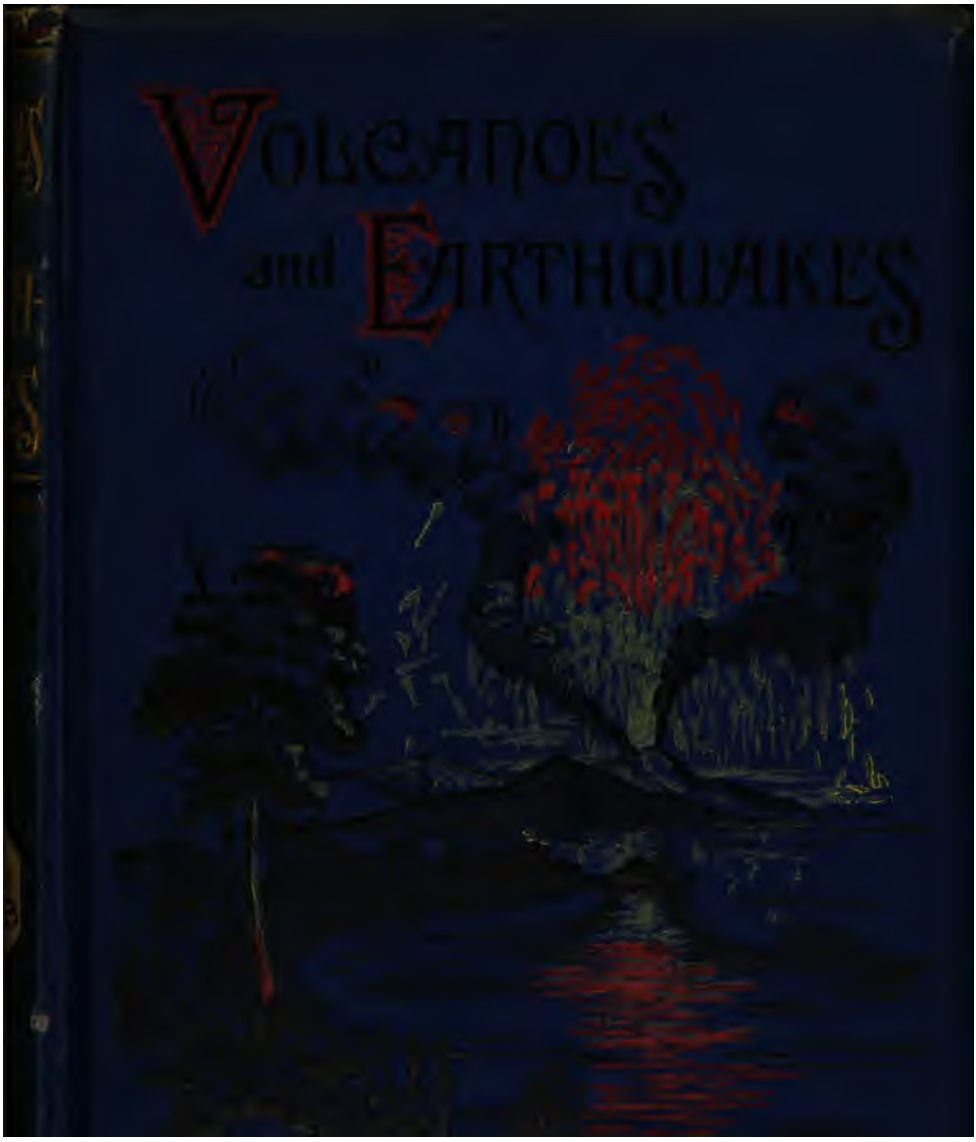
Volcanoes and Earthquakes



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VOLCANOES AND EARTHQUAKES.

THE EARTHQUAKE AT LISBON IN 1755.

VOLCANOES AND EARTHQUAKES

A POPULAR DESCRIPTION OF THE MOVEMENTS IN THE EARTH'S CRUST

FROM "THE SUBTERRANEAN WORLD"

BY

DR. G. HARTWIG

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CHAPTER I.

GEOLOGICAL REVOLUTIONS.

The eternal strife between water and fire—Strata of aqueous origin—Tabular view of their chronological succession—Enormous time required for their formation—Igneous action—Metamorphic rocks—Upheaval and depression—Fossils—Uninterrupted succession of organic life.

GEOLOGY teaches us that, from times of the remoteness of which the human mind can form no conception, the surface of the earth has been the scene of perpetual change, resulting from the action and counter-action of two mighty agents—water and subterranean heat.

Ever since the first separation between the dry land and the sea took place, the breakers of a turbulent ocean, the tides and currents, the torrents and rivers, the expansive power of ice, which is able to split the hardest rock, and the grinding force of the glacier, have been constantly wearing away the coasts and the mountains, and transporting the spoils of continents and islands from a higher to a lower level.

During our short historical period of three or four thousand years, the waters, in spite of their restless activity and the considerable local changes effected by their means, have indeed produced no marked alteration in the great outlines of the sea and land; but when we consider that their influence has extended over countless ages, we can no

longer wonder at the enormous thickness of the stratified rocks of aqueous origin which, superposed one above the other in successive layers, constitute by far the greater part of the earth-rind.

Our knowledge of these sedimentary formations is indeed as yet but incomplete, for large portions of the surface of the globe have never yet been scientifically explored; but a careful examination and comparison of the various strata composing the rocky foundations of numerous countries, have already enabled the geologist to classify them into the following chronological systems or groups, arranged in an ascending series, or beginning with the oldest.

1. Laurentian, named from its discovery northward of the River St. Lawrence in Canada.

2. Cambrian
3. Silurian
4. Devonian

These three groups owe their name to their occurrence in Wales and Devonshire, where they were first scientifically explored.

5. Carboniferous. In this group the most important coal-fields are found.

6. Permian, from the Russian province of Permia.

7. Triassic.

8. Lias.

9. Oolite.

10. Cretaceous.

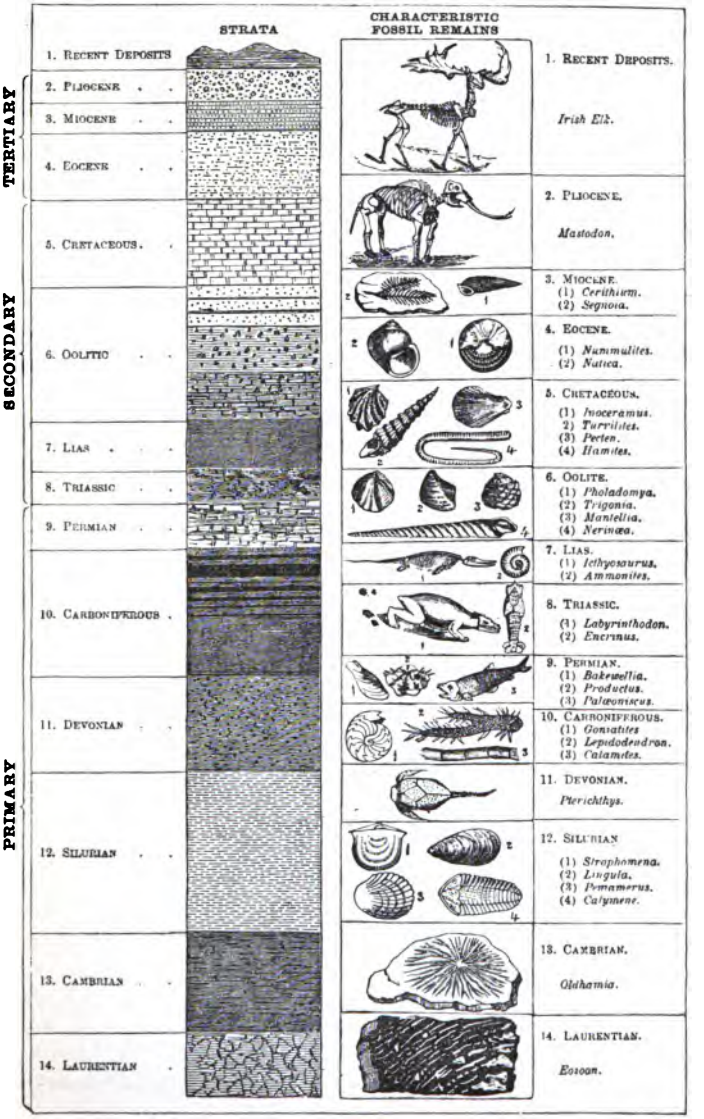
11. Tertiary; subdivided into Eocene, Miocene, and Pliocene.

12. Recent marine and lacustrine strata.

Each of these systems consists again of numerous sections and alternate layers, sometimes of marine, sometimes of freshwater formation, the mere naming of which would fill several pages.

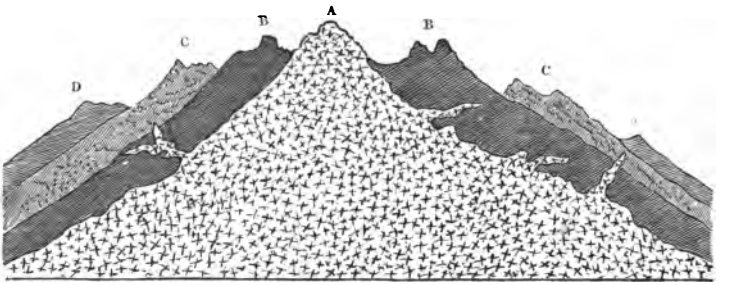
When we reflect that the Laurentian system alone has a thickness of 30,000 feet; that many of the numerous subdivisions of the Triassic or Oolitic group are 600, 800, or even several thousand feet thick, and that each of these enormous sedimentary formations owes its existence to the disintegration of pre-existing mountain masses—we can

TABULAR GEOLOGICAL PROFILE.



form at least a faint notion of the enormous time which the whole system required for its completion.

Had the levelling power of water never met with an antagonistic force, there can be no doubt that the last remains of the dry land, supposing it could ever have risen above the ocean, must long since have been swept into the sea. But while water has been constantly tending to reduce the irregularities of the earth's surface to one dull level, the expansive force of subterranean heat has been no less unceasingly active in restoring the unevenness of the external crust by the ejection or protrusion of new masses of stone



Aqueous Strata Disturbed by Igneous Formations.

B C D, aqueous strata, originally horizontal, raised by protusion of A, granite rock.

(porphyry, trachyte, basalt, lava, &c.), and by the consequent disturbance, in a variety of ways, of the stratified rocks.

Plutonic and volcanic eruptions and upheavings, in their reaction against the levelling tendencies of water, have in many places deranged, broken, fractured, contorted, or raised strata deposited in horizontal layers at the bottom of the sea, or of large inland lakes. Sometimes a huge mass of crystalline rock, glowing from the furnaces of the deep, has, by its irresistible expansion, slowly forced its way through the superincumbent sedimentary formations, which, yielding to the pressure from below, now form vast mountain slopes, or vertical rock walls, or have even been so totally inverted that strata of a more ancient formation

now overlie those of more modern date, and excite the wonder of the puzzled geologist.

Sometimes, also, volcanic eruptions, repeated through a long lapse of ages and constantly accumulating lavas and cinders, have at length piled up large islands, such as Iceland or Madeira, which now raise their summits thousands of feet above the ocean.

But subterranean fire, and its assistant, steam, have not only produced vast mechanical changes; they have also been the frequent causes of great chemical metamorphoses in the rocks subjected to their action. To the calcining, decomposing, and vapour-generating effects of heat, we trace the origin of the marble of Carrara, of alabaster, of gypsum, and all those various species of stone which geologists include under the name of metamorphic rocks.

Besides the more paroxysmal and violent revolutions resulting from the action of subterranean fire, we find that the earth-rind has at all times been subject to slow oscillatory movements of upheaval and subsidence, frequently alternating on the same spot with long periods of rest. The greater part of the actual dry land has been deep sea, and then again land and ocean many times in succession; and doubtless the actual sea bottom would exhibit similar alternations were we able to explore it. The same materials have repeatedly been exposed to all these changes—now raised or poured out by subterranean fires, and then again swept away by the waters; now changed from solid rock into sand and mud, and then again converted, by pressure or heat, into solid rock. Thus the history of the earth-rind opens to us a vista into time no less grand and magnificent than the vista into space afforded by the contemplation of the starry heavens.

The oldest and the newest stratified rocks are composed of the same mineral substances; for clay, sandstone, and limestone occur in the Silurian and in the Carboniferous formation; in the Cretaceous and Triassic systems; in the Tertiary and in the Alluvial deposits, which have immediately preceded the present epoch.

Where then, it may be asked, does the geologist find a chronological guide to lead him through the vast series of strata which, in the course of countless ages, have been deposited in the water? How is he able to distinguish the boundaries of the various periods of creation? Where are the precise indications which enable him to decipher the enigmas which the endless feuds of fire and water have written in the annals of our globe?

The fossil remains of animals and plants wonderfully furnish the guidance which he needs. The corals and shells, the ferns and conifera, the teeth and bones found in the various strata of the earth-rind, are the landmarks which point out to him his way through the labyrinth of the primitive ages of our globe, as the compass directs the mariner over the pathless sea. Every leading fossil has its fixed chronological character, and thus the age of the formation in which it occurs may be ascertained, and its place determined in the geological scale. It would, however, be erroneous to suppose that each successive formation has been the seat of a totally distinct creation, and that the organic remains found in one particular stratum are separated by an impassable barrier from those which characterise the preceding or following sedimentary deposits.

As on the surface of the earth or along the shore of the sea, each land or each coast has not only its peculiar plants or animals, but also harbours many of the organic forms of the neighbouring countries or conterminous shores; as the tropical organisations gradually pass into those of the temperate zones, and these again merge into those of the polar regions, so also the stream of life has from the first flowed uninterruptedly, in gradually changing forms, through every following age. New genera and species have arisen, and others have disappeared, some after a comparatively short duration, others after having outlasted several formations; but every extinct form has but made way for others, and thus each period has not only witnessed the decay of many previously flourishing genera and species, but has also marked a new creation.

No doubt the numerous local disturbances above mentioned have frequently broken the chain of created beings; but a gradual progress, a continuous development from lower to more highly organised species, genera, orders, and classes, has from the beginning been the general and constant law of organic life. Universal destructions of existing forms, revolutions covering the whole surface of the earth with ruin, have most assuredly never occurred in the annals of our globe.

Nor must it be supposed that the whole scale of sedimentary formations is to be found superimposed in one spot; for as in our times new strata are chiefly growing at the mouths of rivers, or where submarine currents deposit at the bottom of the ocean the fine mud or sand which is conveyed into the sea by the disintegration of distant mountain chains, so also from the beginning each stratum could only have been deposited in similar localities; and while it was slowly increasing, and not seldom acquiring colossal dimensions in some parts of the globe, others remained comparatively but little altered, until new oscillatory movements produced a change in their former position, and opening new paths to the rolling waters, here set bounds to the progress of one formation, and there favoured the deposition of another.

A complete study of all the various transformations by fire or water which the surface of our earth has undergone would require an elaborate treatise on geology, and lies far beyond the scope or the pretensions of a popular volume. But I should be neglecting some of the most interesting features of the subterranean world, were I to omit all mention of the fossils embedded in its various strata; of its internal heat; of the upheavals and subsidences which have played so conspicuous a part in his history of the earth-rind, and are still proceeding at the present day; of the water percolating or flowing beneath the earth's crust, and finally of the volcanoes and earthquakes, which prove to us that the ancient subterranean fires, far from being extinct, are still as powerful as ever in remodelling its surface.

CHAPTER II.

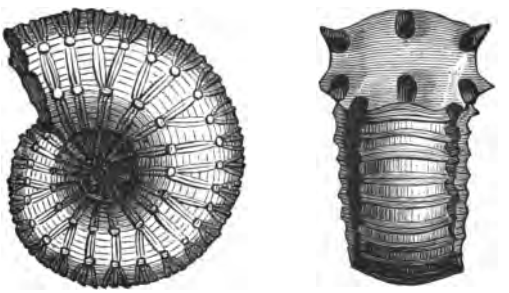
FOSSILS.

General remarks—Eozoon Canadense—Trilobites—Brachiopods—Pterichthys Milleri—Oldest Reptiles—Wonderful preservation of colour in Petrified Shells—Primeval Corals and Sponges—Sea-lilies—Orthoceratites and Ammonites—Belemnites—Ichthyosaurus and Plesiosaurus — Pterodactyli — Iguanodon — Tertiary Quadrupeds — Dinotherium—Colossochelys Atlas—Megatherium—Mylodon—Glyptodon Mammoth — Mastodon — Sivatherium Giganteum—Fossil Ripple-marks, Rain-drops, and Footprints—Harmony has reigned from the beginning.

THE fossil remains of plants and animals, which have successively flourished and passed away since the first dawn of organic life, occupy a prominent place among the wonders of the subterranean world. A medal that has survived the ruin of empires is no doubt a valuable relic, but it seems to have been struck but yesterday when compared with a shell or a leaf that has been buried millions of years ago in the drift of the primeval ocean, and now serves the geologist as a waymark through the past epochs of the earth's history.

If we examine the condition in which the fossils have been preserved in the strata successively deposited on the surface of our globe, we find that in general only parts of the original plant or animal have escaped destruction, and in these fragments also the primitive substance has often been replaced by other materials, so that only their form or their impression has triumphed over time. While soft and delicate textures have either been utterly swept away, or could only be preserved under the rarest circumstances (as,

for instance, the insects and flowers enclosed in amber), a greater degree of hardness or solidity naturally gave a better chance of escaping destruction. Thus among plants the most frequent fossil remains are furnished by stems, roots, branches, fruit-stones, leaves; and, among animals, by corals, shells, calcareous crusts, teeth, scales, and bones. But the few memorials that have thus survived the lapse of ages enable us to form some idea of the multitudes that have entirely perished; and the petrified shell of the Ammonite, or the jointed arms of the Encrinite, are proofs of the existence of the world of tiny beings which served them for their nourishment and have been utterly swept



Ammonites Henleyi (Middle Lias).

away. If we consider that the number of all the known species of fossil plants hardly amount to 3000, while the Flora of the present day, as far as it has been examined by systematical botanists, numbers at least 250,000 species; that the host of living insects is probably still more numerous, although not much more than 1500 extinct species of this class are known to us; and that, finally, the remains of all the extinct crustaceous fishes, reptiles, and warm-blooded animals are far outnumbered by the species actually living—we may form some idea of the vast multitudes that have left no trace behind, and whose total loss will for ever confine within narrow limits our knowledge of the past phases of organic creation. This loss appears still greater

when we consider the enormous extent of time during which the fossils known to us have successively existed, and that a part only of the comparatively small number of the orders, genera, and species to which they belong existed at one and the same epoch. But as, owing to the hard texture and mode of life which are so eminently favourable for the preservation of shells, we have been enabled to collect about 11,000 fossil species, a number not much inferior to that of the molluscs of the present day, we may justly conclude that the more perishable forms of life, of which, consequently, fewer vestiges have been preserved, were comparatively as numerous, and that ever since the first dawn of organic life our earth has borne an immense variety of plants and animals.

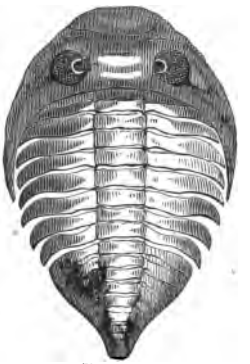
Though comparatively but few species have been preserved, yet sometimes the accumulation of fossil remains is truly astonishing. In the carboniferous strata we not seldom find more than one hundred beds of coal interstratified with sandstones, shales, and limestones, and extending for miles and miles in every direction. How luxuriant must have been the growth of the forests that could produce masses such as these, and what countless multitudes of herbivorous insects must have fed upon their foliage or afforded food to carnivorous hordes scarcely less numerous than themselves! The remains of corals, encrinites, and shells often form the greater part of whole mountain ranges, and, what is still more remarkable, mighty strata of limestone or flint are not seldom almost entirely composed of the aggregated remains of microscopical animals.

After these remarks on fossils in general, I will now briefly point out some of the most striking of the species so preserved to us as they successively appeared upon the stage of life.

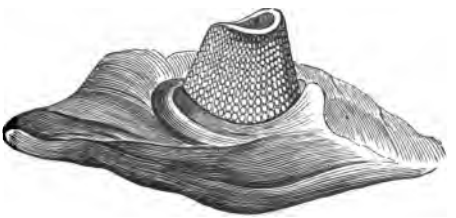
In the Lower Laurentian Rocks, the most ancient strata known, only one fossil has hitherto been found. The *Eozoon Canadense*, as it has been called, belonged to the Rhizopods, which occupy about the lowest grade in the scale of animal existence. Its massive skeletons, composed of innumer-

able cells, would seem to have extended themselves over submarine rocks, their base upwards of twelve inches in width and their thickness from four to six inches. Such is the antiquity of the Eozoon that the distance of time which separated it from the Trilobites of the Cambrian formation may be equal to the vast period which elapsed between these and the Tertiary ages. In other words, it is beyond our imagination to conceive.

In the next following Cambrian formation we find, besides some zoophytes and shells, a number of Trilobites, which, however, appear to have been most abundant in the Silurian Seas, where they probably swarmed as abundantly as the crabs and shrimps in the waters of the present age. Few fossils are more curious than these strange crustaceans, which so widely differ from their modern relatives. The jointed carapace is divided into three lobes, the middle prominent one forming the axis of the body, while the lateral ones were free appendages, under which the soft membranaceous swimming feet were concealed. Large eyes, resembling those of a dragon-fly, projected from the odd crescent-shaped head, and, being composed of many hundred spherical facets, commanded a wide view of the horizon. Provided with such complicated organs of vision, the helpless animal could betimes perceive the approaching enemy, or more easily espy its prey, consisting, most likely, of the smaller marine annelides or molluscs. From the structure of these remarkable eyes we



Trilobite.



Magnified Eye of Trilobite.

may conclude that the waters of the old Cambrian or Silurian Ocean were as limpid as those of the present seas, and that the natural relations of light to the eye and of the eye to light cannot have greatly changed since that period. Many, if not all, of the Trilobites were capable of rolling themselves up into a ball, like wood-lice; and accordingly it is found that in many of them the contour of the head and tail is so constructed that they fit accurately when rolled up. Most probably the Trilobites either swam in an inverted position, the belly upwards, or crawled slowly along at the bottom of the shallow coast waters, where they lived gregariously in vast numbers.

Contemporaneous with the Trilobites were the Eurypterids, which vary from one foot to five or six feet in length. One of the most striking characteristics of this remarkable order of crustaceans is the formidable pair of pincers with which they were armed. As their whole structure shows them to have been active swimmers, they must have made considerable havoc among the smaller fry of the Devonian and Silurian Seas.

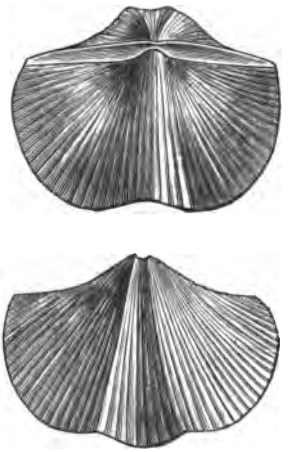
Then also abounded in hundreds of species the Brachiopods, a class of molluscs now but feebly represented by a scanty remnant. The greater part of the interior of the shell, consisting of two unequal valves, is occupied with branching arms, furnished with cilia, which cause a constant current to flow towards the mouth of the mollusc, and thus provide for its nourishment. The arms, as in the family of the Spiriferidæ, are sometimes supported by calcareous skeletons, arranged like loops or spirals.

Some Brachiopods are attached to stones, like oysters; in others the larger valve is perforated, and a sinewy kind of foot, passing through the aperture, serves as a holdfast to the animal.

Most of these helpless creatures did not survive the Carboniferous period, but the Terebratulæ, which still have their representatives in the modern seas, existed even then, so that their genealogical tree may justly boast of a very high antiquity.

The fishes, of which the oldest known specimen has been found in the Upper Silurian group (Lower Ludlow), become more frequent in the next following Devonian epoch, where they appear in a variety of wonderful forms, widely different

Pterygotus Acuminatus (Eurypterid).



Spirifer Princeps (Brachiopod).

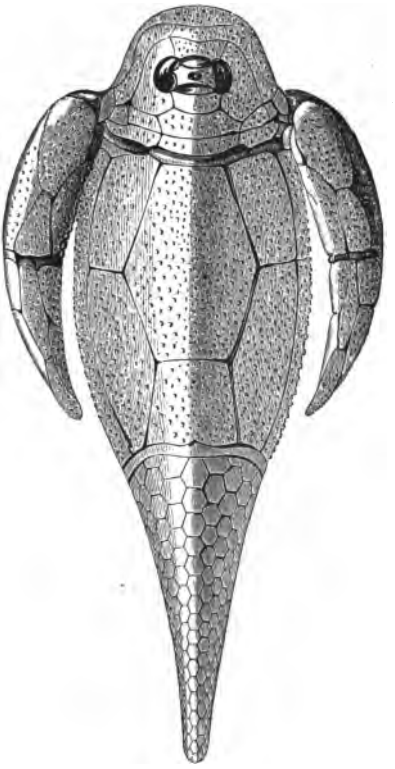
from those of the present day. While in nearly all the existing fishes the scales are flexible, and generally either of a more or less circular form (cycloid), as in the salmon, herring, roach, &c., or provided with comb-like teeth, pro-

jecting from the posterior margin (ctenoid), as in the sole or perch, the fishes of the Devonian, Permian, and Carboniferous periods were decked with hard bony scales, either covered with a brilliant enamel, as in our sturgeons (ganoid), and arranged in regular rows, the posterior edges of each slightly overlapping the anterior ones of the next, or irregular in their shape, and separately embedded in the skin (placoid), as in the sharks and rays of the present day. With rare exceptions their skeleton was cartilaginous; but the less perfect ossification of their bones was amply compensated by the solid texture of their enamelled coat of mail, which afforded them a better protection against enemies and injuries from without than is possessed by any bony-skeletoned fish of our days. They were, in fact, comparatively as well prepared for a hostile encounter as an ancient knight in armour, or as one of our modern iron-plated war ships. One of the most remarkable of these mail-clad Ganoids was the *Pterichthys Milleri* of the Old Red Sandstone of Scotland. In most of our fishes the pectoral fins are but weakly developed; here they constitute real arms, moved by strong muscles, and resembling the paddle of the turtle.

Besides the enormous masses of vegetable matter which distinguish the Carboniferous period, the stone beds of that formation likewise contain a vast number of animal remains. From the reptiles and fishes down to the corals and sponges, many new families, genera, and species crowd upon the scene, while many of the previously flourishing races have either entirely disappeared, or are evidently declining. Thus the Trilobites, formerly so numerous, are reduced to a few species in the Carboniferous period, and vanish towards its close.

In 1847 the oldest known reptiles were found in the coal-field of Saarbrück, in the centre of spheroïdal concretions of clay ironstone, which not only faithfully preserved the skulls, teeth, and the greater portions of the skeletons of these ancient lizards, but even a large part of their skin, consisting of long, narrow, wedge-shaped, tile-like, and

horny scales, arranged in rows. What a lesson for human pride! The pyramid of the Pharaoh Cheops, reared by the labour of thousands of slaves, has been unable to preserve his remains from spoliation even for the short

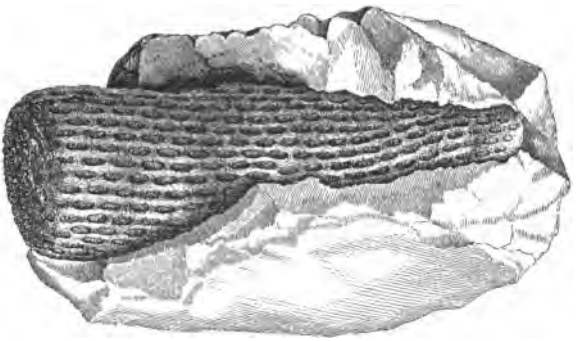


Pterichthys Milleri—Restored (Old Red Sandstone of Scotland).

space of a few thousand years, and here a vile reptile has been safely embedded in a sarcophagus of iron ore during the vast period of many geological formations.

Still more recently (1854) other wonders have been

brought to light in the clay ironstone of Saarbrück. The wing of a grasshopper, with all its nerves as distinctly marked as if the creature had been hopping about but yesterday, some white ants or termites (now confined to the warmer regions of the globe), a beetle, and several cockroaches, give us some idea of the insects that lived at the time when our coal-beds were forming. Another highly interesting circumstance, relating to the fossils of that distant period, is that in several of them the patterns of their colouring have been preserved. Thus *Terebratula hastata* often retains the marks of the original coloured stripes which ornamented the living shell. In *Aviculo-*



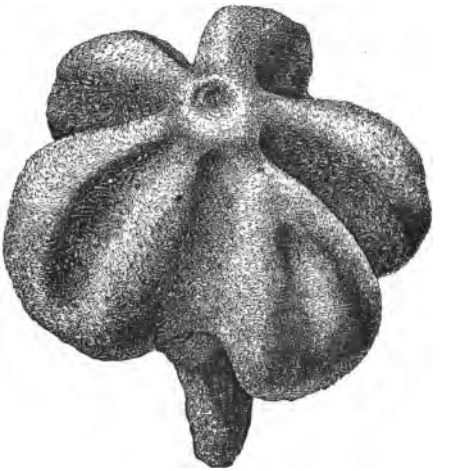
Ventriculites—Fossil Sponge (Chalk).

pecten sublobatus dark stripes alternate with a light ground, and wavy blotches are displayed in *Pleurotomaria carinata*. From these facts Professor Forbes inferred that the depth of the seas in which the Mountain Limestone was formed did not exceed fifty fathoms, as in the existing seas the Testacea, which have shells and well-defined patterns, rarely inhabit a greater depth.

The Magnesian Limestone or Permian group is remarkable chiefly for the vast number of fishes that have been found in some of its members, such as the marl slate of Durham, and the Kupferschiefer, or copper slate of Thuringia. From the curved form of their impressions, as if

they had been spasmodically contracted, the fossil fish of the latter locality are supposed to have perished by a sudden death before they sank down into the mud in which they were entombed. Probably the copper which impregnates the stratum in which they occur is connected with this phenomenon. Mighty volcanic eruptions corrupted the water with poisonous metallic salts, and destroyed in a short time whole legions of its finny inhabitants.

From the earliest ages the corals play a conspicuous part



Siphonia Costata—Fossil Sponge (Green Sand, Warminster).

in fossil history; and as in our days we find them encircling islands and fringing continents with huge ramparts of limestone, so many an ancient reef, now far inland, and raised several thousand feet above the level of the sea, bears witness to the vast terrestrial changes that have taken place since it was first piled up by the growth of countless zoophytes.

With regard to the dimensions of the fossil corals, we do not find that any of them exceeded in size their modern relatives; but their construction was widely different.

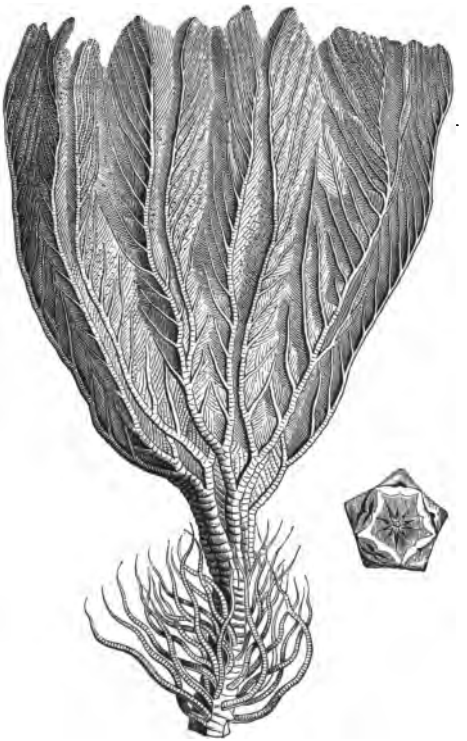
The fossil sponges of the primitive seas are likewise very unlike those of the present day.

Encrinus Liliiformis (Muschelkalk, Germany).

Thus in all the ancient strata we find abundant spongidæ with a stony skeleton, while all the modern sponges possess a horny frame. The Petrospongidæ, or stone sponges, which have long since disappeared, are frequently shapeless masses; but a large number are cup-shaped, with a central tubular cavity, lined, as well as the outer surface, with pores more or less regularly arranged.

The Crinoids, or Sea-lilies, now almost entirely extinct, were extremely common in the primeval seas. Unlike our modern sea-stars, to which they are allies, they did not move about freely from place to place, but were affixed, like flowers, to a slender flexible stalk, composed of numerous calcareous joints connected together by a fleshy coat. The Carboniferous Mountain Limestone is loaded with their remains, and the *Encrinus liliiformis* is one of the leading fossils of the Muschelkalk of the Triassic group. The *Pentacrinus briareus* is of more modern date, and occurs in tangled masses, forming thin beds of considerable extent in the Lower Lias. This beautiful Crinoid, with its innumerable tentacular arms, appears to have been frequently attached to the drift-wood of the Liassic sea, like the floating barnacles of the present day. In the still more recent Chalk group is found a remarkable form of star-fish, the *Marsupites ornatus*, which resembles in all respects the Crinoids, except that it is not and never was provided with a stem. It seems to have been rolled lazily to and fro, by the influence of the waves, at the bottom of the sea, and to have been anchored in its place by the action of gravity alone.

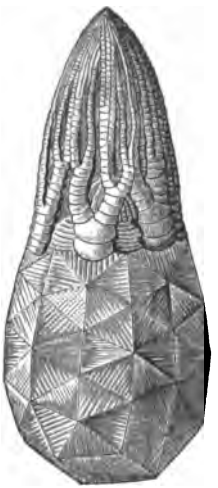
Of all the changes that have taken place in organic life, none perhaps are more remarkable than the transformations which the Cephalopod molluscs have undergone during the various geological eras. In the more ancient Palæozoic seas flourished the Orthoceratites, or straight-chambered



Pentacrinus Briareus.

shells, resembling a nautilus uncoiled. In the Carboniferous ages the Goniatites acquired their highest development. These shells were spirally wound, having the lobes of the chambers free from lateral denticulations or crenatures, so as to form continuous and uninterrupted outlines.

Both Orthoceratites and Goniatites disappear in the Triassic times, and are replaced by hosts of Ammonites, which successively flourished in more than 600 species, and are characterised by an external siphon and chambers of complicated, often foliated, pattern. This foliated structure gives a remarkable character to the intersection of the chamber partitions with the shell, and must have added greatly to the strength of the shell, which was always delicate and often very beautiful. The Ammonites, which made their first appearance towards the end of the Triassic period, abounded in the Oolitic and Cretaceous periods, and were replaced by new forms before the Tertiary beds were deposited. Among these we find the *Ancyloceras gigas,* which may be regarded as an Ammonite partially unrolled, and the *Turrilites tuberculatus,* which has the form and peculiar symmetry of a univalve shell.



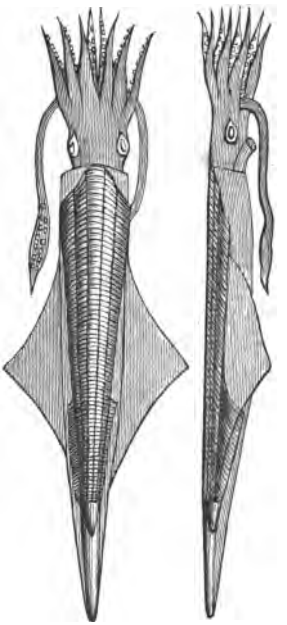
Marsupites Ornatus (Chalk).

In several of the older rocks, especially the Lias and Oolite, Belemnites are frequently met with. These singular dart, or arrow-shaped fossils, were supposed by the ancients to be the thunderbolts of Jove, but are now known to be the petrified internal bones of a race of voracious cuttle-fishes, whose importance in the Oolitic or Cretaceous Seas may be judged of by the frequency of their remains and the 120 species that have been hitherto discovered.

Belemnites two feet long have been found, so that, to judge by analogies, the animals to which they belonged as cuttle-bones must have measured eighteen or twenty feet from end to end. Provided with prehensile hooks on their long arms, and with a formidable parrot-like bill, these huge creatures must have proved most dangerous antagonists, even to the well-protected fishes that lived in the

same seas. But of all the denizens of the Mesozoic Ocean none were more powerful than the large marine or enaliosaurian reptiles, which, flourishing throughout the whole of the Triassic period, were lords of all they surveyed down to the end of the Cretaceous epoch. First among these monsters appears the gigantic Ichthyosaurus, which has

Turrilites Tuberculatus.



Restored Belemnite.

been found no less than forty feet long—a creature half fish, half lizard, and combining, in strange juxtaposition, the snout of the porpoise, the teeth of the crocodile, and the paddles of the whale. But the most remarkable of its features is the eye, surpassing a man's head in size, and wonderfully adapted for vision both far and near.

In the quarries of Caen in Normandy, at Lyme Regis in

Dorsetshire, and particularly at Kloster Banz in Franconia, where the largest known specimen has been discovered, entire skeletons of the formidable Ichthyosaurus have been exhumed from the Liassic shale—memorials of the ages long since past, when lands now far removed from the ocean still lay at the bottom of the sea, and formed the domain of gigantic lizards. The enormous jaw-bones of the Ichthyosauri, which in the full-grown animal could be opened seven feet wide, were armed along their whole length with powerful conical teeth, showing them to have been carnivorous, and the half-digested remains of fishes and reptiles found within their skeletons indicate the precise nature of their food. The size of the swallowed object proves also that the cavity of the stomach must have corresponded with the wide opening of the jaws. Thus powerfully equipped for offensive warfare; excellent swimmers from their compressed cuneiform trunk, their long broad paddles, and their stout vertical tail-fin; provided, moreover, with eyes capable of piercing the dim light of the ocean depths, they must have been formidable indeed to the contemporaneous fishes.

Ichthyosaurus Communis.

The Ichthyosaurus was admirably formed for cleaving the waves of an agitated sea; but the Plesiosaurus was equally well organised for pursuing its prey in shallow crooks and bays defended from heavy breakers. Its long swan-like neck no doubt enabled it to drag many a victim from its

hiding-place. While these huge lizards were the terror of the seas, the Pterodactyles, a race of winged lizards, armed with long jaws and sharp teeth, hovered in the air. With the exception of the greatly elongated fifth finger, to which, as well as to the whole length of the arm and body, the membranous wing or organ of flight was attached, the fingers of this strange animal were provided with sharp claws, so that it was probably enabled, like the bat, to suspend itself from precipitous rock-walls.

Plesiosaurus Dolichodeirus
(British Museum—Found in the Lias of Street near Glastonbury).

It is a remarkable fact, that, whereas the Pterodactyles of the older Lias beds did not exceed ten or twelve inches in length, the later forms, found fossil in the Greensand and Wealden beds of the Lower Cretaceous formation, must have been at least 16½ feet long. That these reptiles were not the only

vertebrated animals capable of hovering in the air at the time when the huge Ichthyosaurus was lord of the seas, is proved by a bird about the size of a rook, which was discovered in 1862, in the lithographic slate of Solenhofen in Bavaria, a stone-bed belonging to the period of the Upper Oolite. The skeleton of this valuable specimen, now in the British Museum, is almost entire, with the exception of the head, and retains even its feathers. Still older fossil mammalia have been found near Stuttgart, in the uppermost bed of the Triassic deposits, and in the Lower Oolite of Oxfordshire. These interesting remains, which carry back the existence of the mammals to a very remote period, belong to small marsupial, or opossum-like, animals. The jaws, which are the principal parts preserved, are exceedingly minute, and remarkable for the number and distribution of their teeth, which prove them to have been either insectivorous or rodent.

The remains of the Ichthyosauri and Plesiosauri occur chiefly in the Liassic group, but the more recent Cretaceous (Wealden) formation is distinguished by the presence of still more enormous land saurians. On their massive legs and unwieldy feet these monsters stood much higher than any reptile of our days, and resembled in bulk and stature the elephants of the present world.

The carnivorous Megalosaurus (for its sharply serrated teeth indicate its mode of life) appears to have preceded the gigantic Iguanodon, whose dentition denotes a vegetable food. Like the giant sloths of South America—the Megatherium and the Mylodon—the Iguanodon was provided with a long prehensile tongue and fleshy lips to seize the leaves and branches on which it fed. Professor Owen estimates its probable length at between fifty and sixty feet, and to judge by the proportions of its extremities, and particularly of its huge feet, it must have exceeded the bulk of the elephant eightfold.

During the following Upper Cretaceous epoch flourished the Mosasaurus, a marine saurian, first discovered in the quarries of St. Peter's Mount, near Maestricht, and sup-

posed to have been twenty-four feet in length. But the supremacy of the reptiles was now drawing to its close, and in the Tertiary period we at length see the Mammalia assume a prominent place on the scene of life. The oldest of these Tertiary quadrupeds differ so widely from those of the present day as to form distinct genera. The Palæotheriums, for instance, of which there are seventeen species, varying in dimension from the size of a rhinoceros to that of a hog, combine in their skeleton many of the characters of the tapir, the rhinoceros, and the horse, while the Anoplotheriums, whose size varied from that of a hare to that of a dwarf ass, resembled in some respects the rhinoceros and the horse, and in others the hippopotamus, the hog, and the camel.

In the Miocene epoch many of these more ancient quadrupeds no longer appear upon the scene, while others still flourish in its upper period along with still existing genera, and with forms long since extinct, such as the Dinotherium. This huge animal is particularly remarkable for its two large and heavy tusks, placed at the extremity of the lower jaw, and curved downwards like those in the upper jaw of the walrus. It was formerly supposed to be an herbivorous cretacean, and to have used its anterior limbs principally in the act of digging for roots. The remains on which these speculations were founded were the huge jaws and shoulder-blade discovered at Eppelsheim in Hesse Darmstadt; but an immense pelvis of the animal, measuring six feet in breadth and four and a quarter feet in height, discovered by Father Sanno Solaro, in the department of the Haute Garonne, proves that this supposed aquatic pachyderm was a gigantic marsupial, and that the dependent trunks of the unwieldy animal, instead of serving the purpose of anchoring it to the banks of rivers, answered the more homely, but equally important office, of lifting the young into the maternal pouch. "The remarkable history of the successive discovery of its bones," says Professor Haughton, "and the change of views consequent thereupon, should teach geologists modesty in

the expression of their opinions." During this period also flourished in India, along with many other strange forms of life, the Colossochelys Atlas, a tortoise of the most gigantic proportions, measuring, probably, nearly twenty feet on the curve of the carapace, and dwarfing into insignificance the great Indian tortoise of the present day.

The nearer we approach our own times, the greater becomes the proportion of still existing genera and species; and it is remarkable that as early as the Pliocene epoch we find a geographical distribution of mammalian life analogous to that which now characterises the various regions of the earth.

Thus the fossil monkeys of South America have the nostrils wide apart like all the existing simiæ of the New World, and fossil monkeys with approximated nostrils, the characteristic mark of all the Old World quadrumana, are exclusively found in Asia and in Europe, where now a small species of monkey is confined to the Rock of Gibraltar, but where, in the Upper Miocene times, large long-armed apes, equalling man in stature, lived in the oak forests of France. Thus also South America, where alone sloths and armadilloes exist at the present day, is the only part of the world where, in the younger Tertiary rocks, the remains of analogous mammals—the Megatherium, the Mylodon, and the Glyptodon—have been found.

The Mylodon was a colossal sloth, eleven feet long, and with a corresponding girth. When we consider the huge size of the pelvis and the massiveness of the limbs, we must needs conclude that Professor Owen could not possibly have given the unwieldy animal a more appropriate surname than that of *robustus*.

The Megatherium was of still larger size. Its length was as much as eighteen feet, the breadth of its pelvis was six feet, and the tail, where it was attached to the body, must have measured six feet in circumference. The thigh bone was nearly three times as great as that of the largest known elephant, the bones of the instep and those of the foot being also of corresponding size. The general pro-

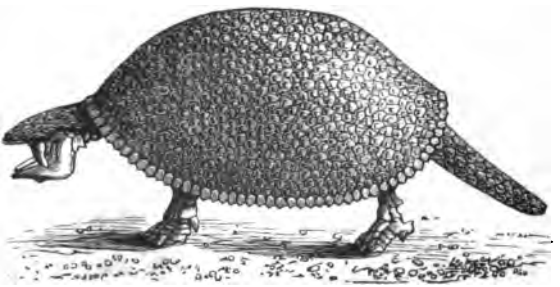
portions both of the Megatherium and Mylodon resembled those of the elephant, the body being relatively as large, the legs shorter and thicker, and the neck very little longer. The Megatherium may have had a short proboscis, but the Mylodon exhibits no mark of such contrivance.

It is evident, from the bulk and construction of these huge animals, that they did not, like the sloths of the present day, crawl along the under side of the boughs till they had reached a commodious feeding place, but that, firmly seated on the strong tripod of their two hind legs and powerful tail, they uprooted trees or wrenched off branches with their fore limbs, which were well adapted for grasping the trunk or larger branches of a tree. The long and powerful claws were also, no doubt, useful in the preliminary process of scratching away the soil from the roots of the trees to be prostrated. This task accomplished, the long and curved fore claws would next be applied to the opposite sides of the loosened trunk. "The tree being thus partly undermined and firmly grappled with, the muscles of the trunk, the pelvis, and hind limbs, animated by the nervous influence of the unusually large spinal cord, would combine their forces with those of the anterior members in the efforts at prostration. If now we picture to ourselves the massive frame of the Megatherium, convulsed with the mighty wrestling, every vibrating fibre reacting upon its bony attachment with a force which the sharp and strong crests and apophyses loudly bespeak, we may suppose that that tree must have been strong indeed which, rocked to and fro, to right and left, in such an embrace, could long withstand the efforts of its ponderous assailant."

The Glyptodon, a colossal armadillo of the size of an ox, was covered with a thick heavy tessellated bony armour, which, when detached from the body, resembled the section of a large cask. This harness measured on its curve from head to tail at least six feet, and four feet from side to side, so that a Laplander might have squatted comfortably under its roof.

In the superficial deposits of diluvial drift, in Germany

and England, in Italy and Spain, in Northern Asia as well as in North America, between the latitudes of 40° and 75°, the bones of the large extinct Pachyderms have been found, and become more and more abundant as we approach the ice-bound regions within the Arctic Circle. The Siberian tundras, and the islands in the Polar Sea beyond, are, above all, so rich in the fossil remains of the Mammoth, or primitive elephant, that its tusks form a not unimportant branch of commerce. From the presence of so large an animal in treeless wilds, where now only small rodents or their persecutors, the Arctic fox and snow owl, find the means of subsistence, it has been inferred that Siberia must in those times have enjoyed a tropical climate; but many



Glyptodon Clavipes.

weighty arguments have been arrayed against this opinion. The musk-ox, it is well known, prefers the stinted herbage of the Arctic regions, while the allied buffalo can only thrive in a warm country, and different species of bears are found in all zones; so also the primitive elephant was formed for a temperate or cold climate. Instead of being naked, like his living Asiatic and African relations, the Mammoth was covered with a warm clothing, well fitted to brave a low temperature, a fact sufficiently proved by the carcass of one of these animals which was found, in the year 1803, embedded in a mass of ice on the bank of the Lena in latitude 70°. Its skin was covered first with black bristles, thicker than horse-hair, from twelve to sixteen

inches in length; secondly, with hair of a reddish-brown colour, about four inches long; and thirdly, with wool of the same colour as the hair, about an inch in length.

The discoveries of Middendorff on the banks of the Taymur likewise show that in those times the climate of Siberia was by no means tropical, for in latitude 75° 15′ he found the trunk of a larch embedded with the bones of a Mammoth in an alluvial stratum fifteen feet above the level of the sea. Fragments of pine leaves have likewise been extracted from cavities in the molar teeth of a fossil rhinoceros, discovered on the banks of the Wiljui, in latitude 64°. The numerous land and freshwater shells accompanying the Mammoth in the highest latitudes are also, almost without exception, identical with those now existing in Siberia.

The Mastodon, though not uncommon among the fossils of the Old World, is more abundantly found in North America. The molar teeth of this huge animal, whose grinding surfaces had their crowns studded with conical eminences, more or less resembling the teats of a cow, differed greatly from the flat-crowned grinders of the Mammoth; but both had twenty ribs like the living elephant, and must have been similar in size and general appearance. The body of the Mastodon would seem to have been longer, its limbs thicker and shorter, and, perhaps, its form, on the whole, rather approaching that of the hippopotamus, which it probably resembled also in some of its habits. Its mouth was broader than that of the elephant, and although it was certainly provided with a long trunk, it must have lived on soft succulent food, and it seems to have rarely left the marshes and muddy ponds, in which it would find ample food.

The most complete, and probably the largest, specimen of the Mastodon ever found was exhumed in 1845, in the town of Newbury, New York, the length of the skeleton being twenty-five feet, and its height twelve feet. From another specimen, found in the same year, in Warren County, New Jersey, the clay in the interior within the ribs, just where the contents of the stomach might natu-

rally have been looked for, furnished some bushels of vegetable substance. A microscopic examination proved this matter to consist of pieces of small twigs of a coniferous tree of the cypress family, probably the young shoots of the white cedar which is still a native of North America.

This interesting discovery likewise proves that the climate of North America was then, like that of Siberia, not very different from that of the present day.

The most remarkable of the fossil Ruminants are found among the deer tribe. The largest of these is the *Sivatherium giganteum*, discovered in the Tertiary beds of the sub-Himalayan hills. It was a deer with four horns, and, to judge by the size of its bones, must have exceeded the elephant in its dimensions. Near this huge "antlered monarch of the waste" the extinct *Cervus megaceros*, found in the bogs and shallow marls of Ireland, appears as a mere dwarf, in spite of its large branching palmate horns, often weighing eighty pounds, and a corresponding stature far exceeding that of our modern deer.

The colossal size of many of the extinct plants and animals might seem to favour the belief that organic life has degenerated from its former powers; but a survey of existing creation soon proves the vital principle to be as strong and flourishing as ever.

No fossil tree has yet been found to equal the towering height of the huge Sequoias and Wellingtonias of California; and though the Horsetails and Clubmosses of the Carboniferous ages may well be called colossal when compared with their diminutive representatives of the present day, yet their height by no means exceeded that of the tall bamboos of India. No fossil bivalve is as large as the Tridacna of the tropical seas; and though our nautilus is a mere pigmy when compared with many of the Ammonites, our naked cuttle-fishes are probably as bulky as those of any of the former geological formations. The living crustaceans and fishes are not inferior to their predecessors in size, and though the giant saurians of the past were much

larger than our crocodiles, yet they do not completely dwarf them by comparison. The extinct Dinornis far surpassed the ostrich in size, but the Mammoth and the Mastodon find their equal in our elephant; and though the sloths of the present day are mere pigmies when compared with the Megatherium, yet no extinct mammal attains the size of the Greenland whale.

The perfect preservation of so many fossil remains of animals and plants, which enables us to trace the progress of organic life on earth from one vast epoch to another, is surely wonderful enough; but we must consider it as a still greater wonder that phenomena usually so evanescent as footprints, ripple-marks, and rain-prints, should in some cases have been permanently engraved in stone, and appear as distinct after millions of years as if their traces had been left but yesterday. All these marks were at first printed on soft argillaceous mud, on the seashore, or on the borders of lakes and rivers, which retained them as they became dry. Sand or clay having then been drifted into the mould by the wind, or deposited in its cavity by the next tide, a permanent cast was made, indented in the lower stratum and standing out in relief on the upper one.

Thus raindrops on greenish slates of the Coal period, with several worm tracks, such as usually accompany rain-marks on the recent mud of modern beaches, have been discovered near Sydney, in Cape Breton. As the drops resemble in their average size those which now fall from the clouds, we may presume that the atmosphere of the Carboniferous period corresponded in density with that now investing the globe, and that different currents of air varied then as now in temperature, so as, by their mixture, to give rise to the condensation of aqueous vapour.

In like manner it has been possible to detect the footprints of reptiles, even in shales as old as the Cambrian formation, and to follow their trail as they walked or crawled along.

In the Upper New Red Sandstone (Lower Trias), near

Hildburghausen, in Saxony, a strange unknown animal, supposed to belong to the frog order, has left footprints bearing a striking resemblance to the impressions made by a human hand; and in the still older red sandstone of Connecticut, a gigantic bird has marked a foot four times larger than that of the ostrich. It existed long before the Ichthyosaurus was seen on earth, and yet by a singular chance its traces, printed on a foundation proverbially unstable, have outlived the wreck of so many ages.

However brief and defective the foregoing review of the fossil world may have been, it has still sufficed to point out the existence on our planet of so many habitable surfaces, each distinct in time, and peopled with its peculiar races of aquatic and terrestrial beings, all admirably fitted for the new states of the globe as they arose, or they would not have increased and multiplied and endured for indefinite periods.

"The proofs now accumulated," says Sir Charles Lyell, "of the close analogy between extinct and recent species, are such as to leave no doubt on the mind that the same harmony of parts and beauty of contrivance which we admire in the living creation has equally characterised the organic world at remote periods. Thus, as we increase our knowledge of the inexhaustible variety displayed in living nature, our admiration is multiplied by the reflection that it is only the last of a great series of pre-existing creations, of which we cannot estimate the number or limit in times past."

CHAPTER III.

SUBTERRANEAN HEAT.

Zone of invariable temperature—Increasing temperature of the earth at a greater depth—Proofs found in mines and Artesian wells, in hot springs and volcanic eruptions—The whole earth probably at one time a fluid mass.

BORN neither to soar into the air, nor to inhabit the deep waters, nor to pass his life in subterranean darkness, man is unable to depart to any considerable distance from the earth's surface. If he ascends in a balloon, he soon reaches the limits where the rarefied atmosphere renders breathing impossible; a few thousand feet limit his efforts to pierce the earth's crust; and should he be cast out into the sea, he is soon drowned. But beyond the limits to which his body is confined, his mind soars into space, and plunging into the unknown interior of our globe, seeks to unravel the mystery of its formation. In the following pages I purpose briefly to point out the circumstances which guide him in his speculations, and enable him to roam, at least in spirit, through the profound abysses of the subterranean world.

As we all know, the temperature of the atmosphere soon communicates its changes to the surface of the earth; and our meadows, which, when warmed by the rays of the sun, are green and covered with flowers, harden in winter into a lifeless plain. But the influence of the sun's heat upon the soil is merely superficial, so that in the temperate zones the annual fluctuations of the thermometer are no longer perceptible at a depth of from 60 to 80 feet.

Thus, in the cellars of the Parisian Observatory, a thermometer, placed many years ago 86 feet below the surface, invariably indicates + 11°7 Celsius; the summer above

may be ever so intensely hot, or the winter ever so cold, the column of mercury never deviates a hair's breadth from the height it has once attained. Below these limits the warmth of the earth gradually increases—a fact placed beyond all doubt by the innumerable observations that have been made in mines, and during the boring of Artesian wells. For wherever sinkings have been made, a rising of the thermometer has always been found to take place as the auger penetrates to a greater depth below the surface. Thus, to cite but a few examples, the temperature of the Artesian well of Grenelle in Paris, which, at a depth of 917 French feet, amounted to + 22°2 C., increased at the depth of 1555 feet to + 26°43, and the water, which now gushes forth from the depth of 1684 feet, constantly maintains the same lukewarm temperature of + 27°70.

During the boring of the well of Neusalzwerk, in Westphalia, the temperature rose at the various depths of 580, 1285, and 1935 feet from + 19°7 C. to + 27°5 and + 31°4, until, finally, when the depth of 2144 feet was attained, the saline spring issued forth with a constant temperature of + 33°6. As from the experience acquired in mines and Artesian wells, the temperature is found to increase by one degree for about every successive 80 or 100 feet, the internal warmth of the earth, supposing it to increase in the same proportion towards the centre, would, at the depth of 10,000 feet, be equal to that of boiling water, and at that of 80 or 100 miles sufficiently great to melt the hardest rock.

Whether this steady increase really takes place is of course only matter of conjecture; but the history of hot springs and volcanic eruptions shows us that everywhere a very high degree of heat exists at considerable depths below the surface.

Most springs in the temperate zone, without being warm in a remarkable degree, still possess a higher temperature than the average warmth of the air in the locality where they gush forth, while in the tropical zone they are frequently cooler—a proof that in both cases they issue from a depth independent of the fluctuating atmospherical influences of the surface. While these cool or cold springs, spread in immense

numbers over the earth, attest the existence everywhere of a subterranean source of heat, the warm and hot springs remind us of its intensity at more considerable depths. These thermal sources are confined to no climate, for in the cold land of the Tschuktschi, where the soil must be perpetually frozen to a depth of several hundred feet, boiling water is found to gush forth, as well as in the tropical Fiji Islands.

The hot springs, though of frequent occurrence in all parts of the world, are not the only or principal vents of subterranean heat. Far greater quantities of caloric are constantly pouring forth from the numerous volcanoes and solfataras, which are likewise distributed all over the surface of the globe. The violent convulsions which attend every outflow of lava are proofs that these torrents of liquid stone must have been forced upwards from a far greater depth than the water of the hot springs. The temperature necessary for their production likewise points to this fact, for to melt stones a heat of at least 2000° C. is required. But volcanoes, like hot springs, are found in every zone; beyond the Arctic Circle, as well as in the most southern land attained by Sir James Ross in his memorable voyage. They line the coasts of the Pacific, as well as those of the Sea of Kamtschatka. They desolate Iceland as they devoured Pompeii and Herculaneum; and everywhere they pour forth the same masses of fluid stone; so that the geologist is not able to distinguish the lavas of the Andes chain from those of Etna or Vesuvius. But phenomena so much alike in character, common to all parts of the globe, can hardly be dependent upon mere local circumstances, and speak loudly in favour of the theory which supposes our earth to have been at one time a ball of liquid fire. Wandering through space during a course of unnumbered ages, this huge mass of molten stones and metals gradually cooled, and at length got covered with a solid crust, below which the ancient furnaces are still burning, and striving to burst their fetters. Well may we say with Horace—

"*Incedimus* per ignes
Suppositos cineri doloso."

CHAPTER IV.

SUBTERRANEAN UPHEAVALS AND DEPRESSIONS.

Oscillations of the Earth's surface taking place in the present day—First ascertained in Sweden—Examples of contemporaneous upheaval and depression in France and England—Probable causes of the phenomenon.

WHILE the sea and the atmospheric ocean are subject to perpetual fluctuations, and the poet justly compares the uncertain tenure of human prosperity with the restless wave or the inconstant wind, the solid earth is generally regarded as the emblem of stability. But an examination of the various strata of aqueous origin which constitute by far the greater part of the actual dry land soon shows the fallacy of this opinion.

The fossils of marine origin which occur in so many of our oldest rocks, now situated far above the level of the ocean, must necessarily have been raised from the deep. On the towering Andes, fifteen thousand feet above the tide-marks of the Pacific, the geologist finds sea-shells embedded in the rock, and high above the snow-line the chamois-hunter of the Alps wonders at the sight of spirally-wound Ammonites that once enjoyed life at the bottom of the Liassic Sea. In strata of a more modern date, we find, on the banks of the river Senegal, far inland, large deposits of the *Arca senilis;* a mollusc still living on the neighbouring coast. On the borders of Loch Lomond, twenty feet above the level of the sea, shells of the edible cockle and sea-urchin repose in a layer of brown clay, and the banks of the Forth and of the Clyde, thirty feet higher

than the storm tides, enclose remains of common shells of the present period, such as the oyster, the mussel, and the limpet. Along the shores of the Mediterranean, at Monte Video and at Valparaiso, in the isles of the Pacific and at the Cape, in California and Haiti, we meet with similar instances of elevation, which, though geologically recent, may yet be of a sufficiently ancient date to have preceded the appearance of man on earth. But proofs are not wanting that the upheaving power which has wrought so many changes in the past is still actively employed in remodelling the surface of the earth.

This important geological fact was first ascertained on the coast of Sweden, where the peculiar configuration of the shore makes it easy to appreciate slight changes in the relative level of land and water. For the continent is fringed with countless rocky islands called the "skär," within which boats and small vessels sail in smooth water even when the sea without is strongly agitated. But the navigation is very intricate, and the pilot must possess a perfect knowledge of the breadth and depth of every narrow channel, and the position of innumerable sunken rocks. On such a coast even a slight change of level could not fail to become known to the mariner, and to attract the attention of the learned, as soon as the book of nature began to be more accurately studied.

Early in the last century the Swedish naturalist Celsius collected numerous observations, all pointing to the fact of a slow elevation of the land. Rocks both on the shore of the Baltic and the German Ocean, known to have been once sunken reefs, were in his time above water; small islands in the Gulf of Bothnia had been joined to the continent, and old fishing-grounds deserted, as being too shallow, or entirely dried up. These changes of level, which he estimated at about three feet in a century, Celsius attributed to a sinking of the waters of the Baltic, owing possibly to the channel, by which it discharges its surplus waters into the Atlantic, having been gradually widened and deepened by the waves and currents. But

the lowering of level would in that case have been uniform and universal over that inland sea, and the waters could not have sunk at Torneo while they retained their former level at Copenhagen, Wismar, Stralsund, and other towns which are now as close to the water's edge as at the time of their foundation. Playfair (1802) and Leopold von Buch (1807) first attributed the change of level to the slow and insensible rising of the land, and the subsequent investigations of Sir Charles Lyell in 1834 have placed the fact beyond a doubt.

The attention of geologists having once been directed to the partial upheaval of the Scandinavian peninsula, similar facts were soon pointed out in other countries. At Bourgneuf, near La Rochelle, the remains of a ship wrecked on an oyster bank in the year 1752, now lie in a cultivated field, fifteen feet above the level of the sea; and within a period of twenty-five years the parish has gained at least 1500 acres, a very acceptable gift of the subterranean plutonic power. Port Bahaud, where formerly the Dutchmen used to take in cargoes of salt, is now 9000 feet from the sea, and the Island of Olonne is at present surrounded only by swamps and meadows. These and similar phenomena, such as the constant rise of the chalk cliffs at Marennes, cannot possibly be explained by recent driftings, but evidently proceed from a slow upheaval of the coasts and the adjacent sea-bed.

On the opposite shores of the Atlantic, we find Newfoundland undergoing a similar process of elevation; for cliffs over which, thirty or forty years ago, schooners used to sail with perfect safety, are now quite close to the surface; and in the Pacific the depth of the channel leading to the port of Honolulu is gradually decreasing from the same cause.

While many coasts thus show signs of progressive elevation, others afford no less striking proofs of subsidence, frequently in close proximity to regions of upheaval.

Thus on the south-west coast of England, in Cornwall, Devon, and Somerset, submarine forests, consisting of the

species still flourishing in the neighbourhood, are of such frequent occurrence that, according to Sir Henry de la Beche, "it is difficult not to find traces of them at the mouths of all the numerous valleys which open upon the sea." Sometimes they are covered with mud or sand, and generally the roots are found in the situation where they originally grew, while the trunks have been horizontally levelled. At Bann Bridge, specimens of ancient Roman pottery have been discovered twelve feet below the level of the sea, and the remains of an old Roman road, now submerged six feet deep, prove that the subsidence of the land has been going on since the times of Julius Cæsar and Agricola.

On the east coast the phenomenon is still more striking, particularly in the Wash, that shallow bay between Lincolnshire and Norfolk, on whose opposite shores a submarine forest extends, the trunks and stubbles of which become apparent at ebb-tide. On the coasts of Normandy and Brittany we likewise find traces of depression, pointing to some future time when perhaps many a bluff headland, now boldly fronting the ocean, may have disappeared beneath the waves.

Huts of the Esquimaux and of the early Danish colonists on the coast of Greenland, now submerged at high tide, could not possibly have been originally constructed in so inconvenient a situation; and at Puynipet, in the South Sea, habitations sunk beneath the water likewise prove a gradual subsidence of the land.

On many coasts and islands modern scientific explorers have hewn marks in the rock, to enable future generations to judge of the changes which are slowly and surely altering the configuration of the land and tracing new boundaries to the ocean. Had our forefathers left us similar memorials, we should know much more about the oscillatory movements of the earth-rind than we know now; but, unfortunately, experimental natural philosophy is but of recent date, and the marks chiselled out upon the Swedish rocks in the years 1731 and 1752 are the earliest records

by which the chronological progress of elevation or subsidence can be distinctly ascertained.

This phenomenon, which has played so important a part in the physical annals of our globe, having once been accurately determined, enables the geologist to explain many facts for which, before it became known, it was impossible to account.

We now need not wonder at seeing sea-shells embedded in the highest mountains or buried hundreds of fathoms under the ground, at alternating layers of marine and sweet-water deposits being frequently storied one above the other, or at originally horizontal strata being now found at every possible angle of inclination.

The imperceptible slowness with which many of these vast changes are actually taking place warrants the inference that violent volcanic revolutions have no doubt been far less instrumental in moulding the earth-rind to its present form than the slow oscillatory movements of elevation and depression which from time immemorial have been constantly altering its surface.

The causes of these oscillatory movements are still very imperfectly known, though a probable hypothesis attributes them to the expansion by increased temperature of extensive deep-seated masses of matter. As the elevation of some tracts seem to coincide with the proportionate depression of others at a greater or less distance, these alternating upheavals and subsidences may possibly be the result rather of the lateral shifting of the flow of heat from one mass of subterranean matter to a neighbouring mass than of its positive increase on the whole. "Such a lateral division of the outward flow of heat," says Mr. Poulett Scrope, "we may presume to be caused by the deposition over certain areas of thick newly-formed beds of any matter imperfectly conducting heat, like sedimentary sands, gravels, clays, shales, or calcareous mud, by which the outward transmission of heat being checked, it must accumulate beneath, while a portion of it will pass off laterally to augment the temperature of mineral matter in neighbouring areas; just

as the water of a spring, if its usual issue is blocked up, will accumulate in the fissures or pores of the rock containing it, until it finds a vent on either side and at a higher level. Owing to this increase, the resistance opposed by the overlying rocks in that quarter may be sooner or later overcome, and their elevation brought about, through the dilatation of the mineral matter beneath."

CHAPTER V.

SUBTERRANEAN WATERS AND ARTESIAN WELLS.

Subterranean distribution of the waters—Admirable provisions of Nature—Hydrostatic laws regulating the flow of springs—Thermal springs—Intermittent springs—The Geyser—Bunsen's theory—Artesian wells—Le Puits de Grenelle—Deep borings—Various uses of Artesian wells—Artesian wells in Venice and in the Desert of Sahara.

In every zone the evaporating power of the sun raises from the surface of the ocean vapours, which hover in the air until, condensed by cold, they descend in rain upon the earth. Here part of them are soon restored to the sea by the swollen rivers; another part is once more volatilised; but by far the larger quantity finds its slow way into the bowels of the earth, where it serves for the perennial supply of wells and springs.

The distribution of these subterranean waters, and the simple laws which regulate their circulation, afford us one of the most interesting glimpses into the physical economy of our globe. We know that the greater part of the earth's surface is composed of stratified rocks, or alternate beds of impermeable clay and porous limestone or sand, which were originally deposited in horizontal layers, but have since been more or less displaced and set on edge by upheaving forces. Wherever permeable beds of limestone or sand crop out on the surface of the land, the residuary portions of rain-water which are not disposed of by floods or by evaporation must necessarily penetrate into the pores and fissures, and descend lower and lower, until they finally

reach an impermeable stratum which forbids their further progress to a greater depth.

The granite, gneiss, porphyry, lava, and other unstratified and crystalline rocks of igneous origin, which cover about a third part of the habitable globe, are likewise intersected by innumerable fissures and interstices, which in a similar manner collect and transmit rain-water.

Thus the plutonic or volcanic forces which have gradually moulded the dry land into its present form have also provided it with the necessary filters, drains, reservoirs, and conduits for the constant replenishment of springs, brooks, and rivers. As every porous layer is more or less saturated with moisture, the stratified rocks are frequently traversed at various depths by distinct sheets of water, or rather, in most cases, by permanently drenched or waterlogged sheets of chalk or sand. Thus, in a boring undertaken in search of coal at St. Nicolas d'Aliermont, near Dieppe, no less than seven very abundant aquiferous layers or beds of stone were met with from about 75 to 1000 feet below the surface. In an Artesian boring at Paris, five distinct sheets of water, each of them capable of ascension, were ascertained; and similar perforations executed in the United States, and other countries, have in the same manner traversed successive stages of aqueous deposits.

Thus there can be no doubt that vast quantities of water are everywhere accumulated in the porous strata of which a great part of the superficial earth-rind is composed, the rapidity with which they circulate varying of course with the amount of hydrostatic pressure to which they are subjected, and the more or less porous and permeable nature of the beds through which they percolate. Were the ground we stand on composed of transparent crystal, and the subterranean watercourses tinged with some vivid colour, we should then see the upper earth-crust traversed in every direction by aqueous veins, and frequently as saturated with water as the internal parts of our body are with blood. But Nature not only perennially feeds our

springs and brooks from the inexhaustible fountains of the deep; it is also one of her infinitely wise provisions that the same water which, if placed in casks or open tanks, becomes putrid, continues fresh so long as it remains in the cavities and interstices of the terrestrial strata. While filtering through the earth, it is generally cleansed of all the organic substances whose decay would inevitably taint its purity, and comes forth salubrious and refreshing, a source of health and enjoyment to the whole animal creation.

The extreme limits to which the waters descend into the earth of course escape our direct observation, as the lowest point to which the subterranean regions have been probed is less than 2000 or 2500 feet below the level of the sea; but as we know from the formation of many basins that the strata of which they are composed attain in many cases a thickness of from 20,000 to 30,000 feet, there can hardly be a doubt that they are permeated by water to an equal depth.

As steam plays so great a part in volcanic phenomena, the seat or effective cause of which must needs be sought for at an immense distance below the surface of the earth, we have another proof of the vast depth to which the subterranean migrations of water are able to attain.

After this brief glimpse into the reservoirs of the deep, we have to ascertain the power which raises their liquid contents and forces them to reappear upon the surface of the earth. If we pour water into a tube, bent in the form of the letter U, it will rise to an equal level in both branches. We will now suppose that the left branch of the tube opens at the top into a vast reservoir, which is able to keep it constantly filled, and that the right branch is cut off near the bottom, so that only a small vertical piece remains. The pressure of the water column in the left branch will in this case force the liquid to gush out of the orifice of the shortened right branch to the level which it occupied while the branch was still entire.

These two hydrostatic laws, or rather these two modifications of the same law, have been frequently put to practical uses; as, for instance, in the communicating tubes which distribute the waters of an elevated source or reservoir to the various districts of a town, or in the subterranean conduits which serve to create fountains, such as those of Versailles or the Crystal Palace.

When the Romans intended to lead water from one hill to another, they constructed, at a vast expense, magnificent aqueducts across the intermediate valley; but the Turks, whom we look upon as ignorant barbarians, obtain the same result in a much more economical manner, and in this respect far surpass the ancients, who, had they been better acquainted with the first principles of hydrostatics, would indeed have left us fewer specimens of their architectural skill, but would at the same time have saved themselves a great deal of unnecessary expense.

Down the slope of the hill from which the water is to be conducted, the Turks lay a tube of brick or metal, which, crossing the valley, moulds itself to its different inflections, and ultimately ascends the declivity of the hill on the opposite side, where, in virtue of the law above cited, the water rises as high as on that from which it descended. If we suppose the descending branch of the tube to be prolonged only as far as the level of the valley, with a superficial orifice, then the liquid will of course gush forth in a vertical column, and form a *jet d'eau*, or fountain, its height being determined by the elevation of the sheet of water by which it is fed, and the consequent degree of pressure which acts upon it. This is the principle on which all artificial fountains are constructed. The conduit, for instance, which feeds the grand fountain of the Tuileries receives its water from a reservoir situated on the heights of Chaillot.

Whatever the form of the tube may be in which the liquid is contained, the simple hydrostatic law which regulates its level remains unmodified. Let the tube be circular, elliptic, or square, with a single orifice or with

many—let it be open or choked with pebbles or permeable sand—in every case the water will invariably rise to the same height, provided the tube be perfectly water-tight; or else gush forth wherever it finds an opening below the highest level.

This hydrostatic principle so perfectly illustrates the origin of springs, that it is almost superfluous to enter into any further details on the subject.

When we consider that porous or absorbent strata, alternating with impermeable strata, frequently crop out on the back or on the slope of hills or mountains, and then, having reached their base, extend horizontally beneath the plain, there can be no doubt that they are placed in the same hydrostatic conditions as ordinary water-conducting tubes, and that wherever any fissure or opening occurs in the superincumbent impervious strata at any point below the highest level of the water, springs must necessarily be formed.

As the same strata often extend over many hundreds of miles, we cannot wonder that sources frequently issue from the centre of immense plains, for the hydrostatic pressure which causes them to gush forth may have its seat at a very considerable distance.

As the waters by which the springs are fed have often vast subterranean journeys to perform, their temperature is naturally independent of that of the seasons or of the changes of the atmosphere. Thus, cold springs occur in a tropical climate, when their subterranean channels descend from high mountains, and boiling sources gush forth in the Arctic regions when forced upwards from a considerable depth.

While the waters filter through the earth, they also naturally dissolve a variety of substances, and hence all springs are more or less impregnated with extraneous particles. But many of them, particularly such as are of a higher temperature, contain either a large quantity or so peculiar a combination of mineral substances as to acquire medicinal virtues of the highest order.

The geological phenomena which favour the production of thermal springs are extremely interesting, and point to a deep-seated origin. By far the greater number of these fountains arise near the scene of some great subterranean disturbance, either connected with volcanic action, or with the elevation of a chain of mountains, or ascend through clefts and fissures caused by disruption. Thus the thermal springs of Matlock and Bath accompany great natural crevices in the mountain limestone, and the hot springs of Wiesbaden and Ems, of Carlsbad and Toeplitz, all lie contiguous to remarkable dislocations, or to great lines of elevation, or to the neighbourhood of a volcanic focus.

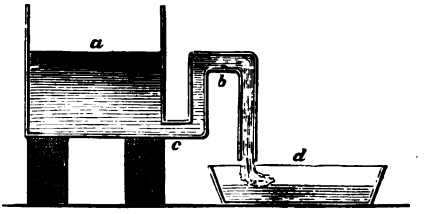
One of the most remarkable phenomena of thermal springs is the constant invariableness of their temperature and their mineral impregnations. During the last fifty or sixty years, ever since accurate thermometrical observations and chemical analyses have been made, the most celebrated mineral sources of Germany have been found to contain the same proportion of mineral substances. This is truly astonishing when we consider that the latter are merely dissolved by the waters while passing through the bowels of the earth, and that a considerable number of them are frequently found together in the same source.

Another remarkable fact is, that, even in countries exposed to violent and frequent earthquakes, so many subterranean watercourses have remained unaltered for 2000 years at least. The sources of Greece still flow apparently as in the times of Hellenic antiquity. The spring of Erasinos, two leagues south of Argos, on the declivity of the Chaonian mountains, is mentioned by Herodotus. At Delphi the Cassotis (now Wells of Saint Nicholas) still flows under the ruins of the Temple of Apollo, and the hot baths of Aidepsos still exist in which Sylla bathed during the Mithridatic war.

Many springs exhibit the singular phenomenon of an intermittence which is independent of the quantity of rain falling in the district, or of the flux and reflux of the tide in a neighbouring river. In many cases the simple and

well-known hydrostatical law exemplified in the common siphon * affords a very ready and sufficient explanation of the phenomenon.

In the annexed diagram the vessel *a* communicates, by a tube *c*, with the siphon tube *b*, and it is manifest that when the water in *a* rises above the level of the top of *b*, it will begin to flow over and escape, as at *d*. But as soon as this is the case the tube *b* begins to act as a siphon, and



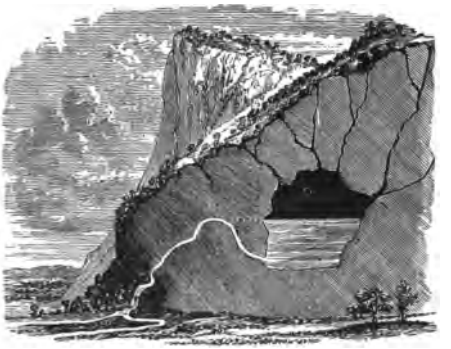
draws off all the water in *a*, so that if a constant supply is poured into *a*, but at a rate slower than the rate of the discharge at *d*, there will be an intermittent discharge, the interval depending on the relation of the rate of filling to that of emptying.

The case of a subterranean cavity in a limestone rock, slowly fed by drainage from the cracks and fissures of the rock above, and communicating at a distant point with the surface by a bent or siphon tube, is evidently strictly analogous.

Iceland, pre-eminently the land of volcanic wonders, pos-

* A siphon, as is well known, is a bent tube, having one leg longer than the other. When this tube is filled with any liquid, and the shorter end is immersed in a vessel containing liquid of the same kind, the weight of the column in the longer leg will cause the liquid to begin to run out, and it will continue running till the vessel is emptied. This arises from the pressure of air on the exposed surface of fluid, forcing it up through the tube to prevent vacuum, which would otherwise be formed at the highest point; and the extreme limit of length at which the siphon will act is therefore determined by the height of a column of the fluid equal to the pressure of the atmosphere (fifteen pounds on the square inch). The limit in the case of water is something more than thirty feet.

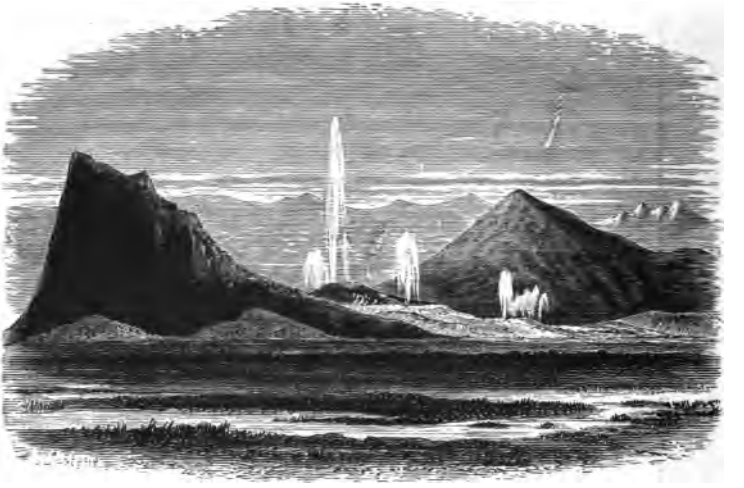
sesses in the Great Geyser the most remarkable intermittent fountain in the world. "At the foot of the Laugarfjall hill, in a green plain, through which several rivers meander like threads of silver, and where chains of dark-coloured mountains, overtopped here and there by distant snow-peaks, form a grand but melancholy picture, dense volumes of steam indicate from afar the site of a whole system of thermal springs congregated on a small piece of ground not exceeding twelve acres in extent. In any other spot the smallest of these boiling fountains would arrest the traveller's attention, but here his whole mind is absorbed by



Section of an Intermittent Spring.

the Great Geyser. In the course of countless ages, this monarch of springs has formed out of the silica which it deposits a mound which rises to about thirty feet above the general surface of the plain, and slopes on all sides, to a distance of a hundred feet or thereabouts, from the border of a large circular basin situated in its centre, and measuring about fifty-six feet in the greatest diameter and fifty-two feet in the narrowest. In the middle of this basin, forming as it were a gigantic funnel, there is a pipe or tube, which at its opening in the basin is eighteen or sixteen feet in diameter, but narrows considerably at a

little distance from the mouth, and then appears to be not more than ten or twelve feet in diameter. It has been probed to a depth of seventy feet, but it is more than probable that hidden channels ramify further into the bowels of the earth. The sides of the tube are smoothly polished, and so hard that it is not possible to strike off a piece of it with a hammer. Generally the whole basin is found filled up to the brim with sea-green water as pure as crystal, and of a temperature of from 180° to 190°.



Geysers of Iceland.

Astonished at the placid tranquillity of the pool, the traveller can hardly believe that he is really standing on the brink of the far-famed Geyser; but suddenly a subterranean thunder is heard, the ground trembles under his feet, the water in the basin begins to simmer, and large bubbles of steam rise from the tube and burst on reaching the surface, throwing up small jets of spray to the height of several feet. Every instant he expects to witness the grand spectacle which has chiefly induced him to visit

this northern land; but soon the basin becomes tranquil as before, and the dense vapours produced by the ebullition are wafted away by the breeze. These smaller eruptions are regularly repeated every eighty or ninety minutes, but frequently the traveller is obliged to wait a whole day or even longer before he sees the whole power of the Geyser. A detonation louder than usual precedes one of

Boiling Springs, United States.

these grand eruptions; the water in the basin is violently agitated; the tube boils vehemently; and suddenly a magnificent column of water, clothed in vapour of a dazzling whiteness, shoots up into the air with immense impetuosity, to the height of eighty or ninety feet, and, radiating at its apex, showers water and steam in every direction. A second eruption and a third rapidly follow, and after a few minutes the fairy spectacle has passed away like a

fantastic vision. The basin is now completely dried up, and on looking down into the shaft, the traveller is astonished to see the water about six feet from the rim, and as tranquil as in an ordinary well. After about thirty or forty minutes it again begins to rise, and after a few hours reaches the brim of the basin. Soon the subterranean thunder, the shaking of the ground, the simmering above the tube begin again—a new gigantic explosion takes place, to be followed by a new period of rest—and thus this wonderful play of nature goes on, day after day, year after year, and century after century. The mound of the Geyser bears witness to its immense antiquity, as its water contains but a minute portion of silica."*

The explanation of these wonderful phenomena has exercised the ingenuity of many natural philosophers; but Professor Bunsen's theory seems the most plausible. Having first ascertained, by experiment, that the water at the mouth of the tube has a temperature, corresponding to the pressure of the atmosphere, of about 212° F., he found it much hotter at a certain depth below; a thermometer, suspended by a string in the pipe, rising to 266° F., or no less than 48° above the boiling point. By letting down stones, suspended by strings, to various depths, he next came to the conclusion that the tube itself is the main seat or focus of the mechanical power which forces the huge water column upwards. For the stones which were sunk to greater distances from the surface were not cast up again when the next eruption of the Geyser took place, whereas those nearer the mouth of the tube were ejected to a considerable height by the ascending water-column. Other experiments also were made, tending to demonstrate the singular fact that there is often scarcely any motion below when a violent rush of steam and water is taking place above. It seems that when a lofty column of water possesses a temperature increasing with the depth, any slight ebullition, or disturbance of equilibrium, in the

* "The Polar World," p. 54.

upper portion may first force up water into the basin, and then cause it to flow over the edge. A lower portion, thus suddenly relieved of part of its pressure, expands, and is converted into vapour more rapidly than the first, owing to its greater heat. This allows the next subjacent stratum, which is much hotter, to rise and flash into a gaseous form; and this process goes on till the ebullition has descended from the middle to near the bottom of the funnel.*

In many geological basins the deep subterranean waters are frequently enclosed over a surface of many square miles between impermeable beds of clay or hard rock, which nowhere permit them to escape; but if a hole be bored deep enough to reach a permeable bed, it is evident that they will then gush forth more or less violently, according to the degree of hydrostatic pressure which acts upon them. This is the simple theory of the Artesian Wells, so called from the French province of Artois, where, as far back as the beginning of the twelfth century, springs of water were artificially obtained by perforating the soil to a certain depth in places where no indication of springs existed at the surface. The barbarous inhabitants of the Sahara seem, however, to have long preceded the Artesians in the art of sinking deep wells; for Olympiodorus, a writer who flourished at Alexandria about the middle of the sixth century, mentions pits, sunk in the oasis to the depth of 200 or 300 yards, and pouring forth streams of water, used for irrigation.

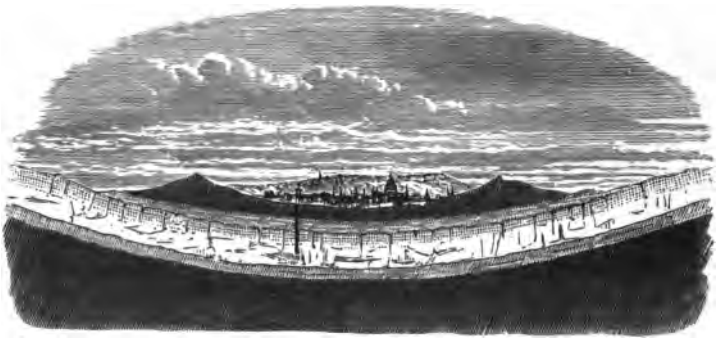
By the aid of geological science, and of greater mechanical skill, Artesian borings are at present frequently undertaken in civilised countries, wherever the nature of the ground promises success, and the want of water is sufficiently great to warrant the attempt. Sometimes the water is reached at a moderate distance from the surface, but not seldom it has been found necessary to bore to a depth of 200 or 300 fathoms. Often efforts, even on this

* Liebig's "Annalen," translated in "Reports and Memoirs of the Cavendish Society," London, 1848, p. 351.

large scale, have proved vain, and the work has been abandoned in despair.

One of the most remarkable instances on record of a successful sinking for water is that of the Artesian well of Grenelle, one of the Parisian suburbs.

The work was begun with an auger of about a foot in diameter, and the borings showed successively the alluvial soil and subsoil, and the tertiary sands, gravels, clays, lignite, &c., until the chalk was reached. The work was then carried on regularly through the hard upper chalk down to the lower chalk with green grains, the dimension



Porous Strata. Artesian Well sunk in the London Basin.

of the auger being reduced at 500 feet to a nine-inch, and at 1300 feet to a six-inch aperture. When the calculated depth of 1500 feet had been reached, and as yet no result appeared, the Government began to be disheartened. Still, upon the urgent representations of the celebrated Arago, the sinking was continued, until at length, at the depth of 1800 feet, the auger, after a violent shock which made the ground tremble, suddenly turned without an effort. "Either the auger is broken, or we have gained our end," exclaimed the director of the work; and a few moments after, a large column of water gushed out of the orifice. It took more than seven years to accomplish this grand

work (1833–41), which was retarded by numberless difficulties and accidents. About half-a-million gallons of perfectly limpid water of a temperature of 82° Fahr. are daily supplied by the Puits de Grenelle, and amply repay its cost (362,432 fr. 65 centimes = £14,500).

The high temperature of Artesian springs, when rising from considerable depths, has been turned to various practical uses. Thus near Canstadt, in Wurtemberg, several mills are kept in work, during the severest cold of winter, by means of the warm water of Artesian wells which has been turned into the mill-ponds, and at Heilbronn several proprietors save the expense of fuel by leading Artesian water in pipes through their greenhouses. In some localities the pure and constantly temperate Artesian waters are made use of for the cultivation of cress. The vigorous growth of this salutary herb in the beds of rivulets, where natural springs gush forth, gave the idea of this application, which is so profitable that the cress nurseries of Erfurt yield a produce of £12,000 a year. Fish ponds have also been improved by such warm springs being passed through them.

Among the localities benefited by the boring of Artesian wells, Venice deserves to be particularly noticed. Formerly the City of the Doges had no other supply of water but that which was conveyed by boats from the Brenta, or obtained from the rain collected in cisterns. Hence the joy of the inhabitants may be imagined, when, in 1846, an Artesian boring in the Piazza San Paolo began to disgorge its water at the rate of forty gallons per minute, and when other undertakings of the same kind proved equally successful.

Wherever a well gushes forth in the Sahara, it brings life into the wilderness; the date-tree flourishes as far as its fertilising waters extend, and the wandering Arab changes into a sedentary cultivator of the soil. Thus the boring of Artesian wells on the desert confines of South Algeria has been the means of wonderful improvement; and if the French have too often marked their dominion

in Africa by a barbarous oppression of the Arabs, they, in this instance at least, appear in the more amiable light of public benefactors.

A boring apparatus was first landed at Philippeville in April 1856, and conveyed with immense difficulty to the Oasis Wad Rir at Tamerna. The work was begun in May, and on the 19th of June, a spring, to which the grateful inhabitants gave the name of the "Well of Peace," gushed forth. Soon after another source was tapped at Tamelhat, in the Oasis Temacen, and received the name of the "Well of God's Blessing."

The beneficent instrument of abundance was now conveyed to the Oasis Sidi Rasched, fifteen miles beyond Tuggurt. Here the auger had scarcely reached a depth of 120 feet when a perfect stream gushed forth, which, according to the praiseworthy Arab custom, received the name of the "Well of Thanks." The opening of this wonderful source gave rise to many touching scenes. The Arabs came in throngs to witness the joyful spectacle: each of them poured some of the water over his head, and the mothers bathed their children in the gushing flood. An old sheik, unable to conceal his emotion, fell down upon his knees, and shedding tears of joy, fervently thanked God for having allowed him to witness such a day.

The next triumph was the boring of four wells in the desert of Morran, where previously no spring had existed. In the full expectation of success, everything had been prepared to turn this new source of wealth to immediate use, and part of a nomadic tribe instantly settled on the spot, and planted 1200 date-trees. A dreary solitude was changed, as if by magic, into a scene of busy life.

These few examples suffice to show the vast services which Artesian wells are destined at some future time to render to many of the arid regions of Africa. Both in the Sahara and in the basin-shaped deserts, which extend, under various names, from the Cape Colony to the neigh-

bourhood of Lake Ngami, there are, beyond all doubt, numberless spots where water, the fertilising element, may be extracted from the bowels of the earth.

In the droughty plains of Australia also a vast sphere of utility is reserved to the Artesian wells. Here, also, they will subdue the desert, unite one coast to another by creating stations in the wilderness, and, with every new source which they call to life, promote both material progress and intellectual improvement.

CHAPTER VI.

VOLCANOES.

Volcanic mountains—Extinct and active craters—Their size—Dangerous crater explorations—Dr. Judd in the Kilauea Pit—Extinct craters—Their beauty—The Crater of Mount Vultur in Apulia—Volcanoes still constantly forming—Jorullo and Isalco—Submarine volcanoes—Sabrina and Graham's Island—Santorin—Number of volcanoes—Their distribution—Volcanoes in a constant state of eruption—Stromboli—Fumaroles—The Lava Lakes in Kilauea—Volcanic paroxysms—Column of smoke and ashes—Detonations—Explosion of cones—Disastrous effects of showers of ashes and Lapilli—Mud streams—Fish disgorged from volcanic caverns—Eruption of lava—Parasitic cones—Phenomena attending the flow of a lava stream—Baron Papalardo—Meeting of lava and water—Scoriæ—Lava and ice—Vast dimensions of several lava streams—Scenes of desolation—Volcanoes considered as safety-valves—Probable causes of volcanoes.

VOLCANOES are vents which either have communicated, or still communicate, by one or several chimney-like canals or shafts, with a focus of subterranean fire, emitting, or having once emitted, heated matter in a solid, semi-liquid, or gaseous state. The first eruption of a volcano necessarily leaves a mound of scoriæ and lava, while numerous eruptions at length raise mountains, which are frequently of an amazing extent and height. These mountains, which are generally called volcanoes, though in reality they are but an effect of volcanic action situated far beneath their base, are called *extinct* when for many centuries they have exhibited no signs of combustion—*active*, when, either perpetually or from time to time, eruptions or

MIDDLE AND VALLEY LAKE CRATERS, MOUNT GAMBIER, SOUTH AUSTRALIA.

exhalations of lava, scoriæ, or gases take place from their summits, or from vents in their sides. Their shape is generally that of a more or less truncated cone; but while some, like Cotopaxi or the Peak of Teneriffe, rise with abrupt declivities in the shape of a sugar-loaf, others, like Mauna Loa in the island of Hawaii, gradually, and almost imperceptibly, ascend from a vast base embracing many miles in circuit.

Their heights also vary greatly. While some, like Madana in Santa Cruz, or Djebel Teir on the coast of the Red Sea, scarcely raise their summits a few hundred feet above the level of the ocean, others, like Chuquibamba (21,000 feet) or Aconcagua (22,434 feet), hold a conspicuous rank among the giant mountains of the earth.

The summit of a volcano generally terminates in a central cavity or crater, where the eruptive channel finds its vent. Craters are sometimes regularly funnel-shaped, descending with slanting sides to the eruptive mouth, but more commonly they are surrounded with high precipitous rock-walls, while their bottom forms a plain, which is frequently completely horizontal, and sometimes of a considerable extent. Its surface is rough and uneven, from the mounds of volcanic sand, or scoriæ, or of hardened lava with which it is covered, and generally exhibits a scene of dreadful desolation, rendered still more impressive by the steam and smoke, which, as long as the volcano continues in an active state, issues from its crevices.

Within this plain the eruptive orifice or mouth of the volcano is almost universally surrounded by an elevation, composed of ejected fragments of scoriæ thrown from the vent. Such cones are forming constantly at Vesuvius, one being no sooner destroyed by any great eruption, before another begins to take shape and is enlarged, till often it reaches a height of several hundred feet.

Thus the crater of an active volcano is the scene of perpetual change—of a continual construction and reconstruction, and the sands of the sea do not afford a more striking image of inconstancy.

The various craters are of very different dimensions. While the chief crater of Stromboli has a diameter of only fifty feet, that of Gunong Tenger, in Java, measures four miles from end to end; and though the depth of a crater rarely exceeds 1000 or 1500 feet, the spectator, standing on the brink of the great crater of Popocatepetl, looks down into a gulf of 8000 feet.

From the colossal dimensions of the larger craters, it may well be imagined that their aspect exhibits some of the sublimest though most gloomy scenery in nature—the picture of old Chaos with all its horrors.

The volcano Gunong Tjerimai, in Java, which rises to the height of 9000 feet, is covered with a dense vegetation up to the crater's brink. On emerging from the thicket, the wanderer suddenly stands on the verge of an immense excavation encircled with naked rocks. He is obliged to hold himself by the branches of trees, or to stretch himself flat upon the ground, so as to be able to look down into the yawning gulf. The inaccessible bottom of the crater loses itself in misty obscurity, and glimmers indistinctly through the vapours slowly and incessantly ascending from its mysterious depths. All is desolate and silent, save when a solitary falcon, hovering over the vast chasm, awakes with her discordant screech the echoes of the precipice. Through a telescope may be seen, in various parts of the huge crater walls, swarms of small swallows, which have there built their nests, flying backwards and forwards. The wandering eye can detect no other signs of life, the attentive ear distinguish no other sound.

Humboldt describes the view down the crater of the Rucul Pichincha—a volcano which towers above the town of Quito to a height of 15,000 feet—as the grandest he ever beheld during all his long wanderings. Guided by an Indian, he ascended the mountain in 1802, and after scaling, with great difficulty, and no small danger, its steep and rocky sides, he at length looked down upon the black and dismal abyss, whence clouds of sulphurous vapour were rising as from the gates of hell.

The descent into the crater of an active volcano is at all times a difficult and hazardous enterprise, both from the steepness of its encircling rock walls, and the suffocating vapours rising from its bottom; but it is rare indeed that a traveller has either the temerity or the good fortune to penetrate as far as the very mouth of the eruptive channel, and to gain a glimpse of its mysterious horrors. When M. Housel visited Mount Etna in 1769, he ventured to scale the cone of stones and ashes which had been thrown up in the centre of the crater, where thirty years before there was only a prodigious chasm or gulf. On ascending this mound, which emitted smoke from every pore, the adventurous traveller sunk about mid-leg at every step, and was in constant danger of being swallowed up. At last, when the summit was reached, the looseness of the soil obliged him to throw himself down flat upon the ground, so that he might be in less danger of sinking, while at the same time the sulphurous exhalations arising from the funnel-shaped cavity threatened suffocation, and so irritated his lungs as to produce a very troublesome and incessant cough. In this posture the traveller viewed the wide unfathomable gulf in the middle of the crater, but could discover nothing except a cloud of smoke, which issued from a number of small apertures scattered all around. From time to time dreadful sounds issued from the bowels of the volcano, as if the roar of artillery were rebellowed throughout all the hollows of the mountain. They were no doubt occasioned by the explosions of pent-up gases striking against the sides of these immense caverns, and multiplied by their echoes in an extraordinary manner. After the first unavoidable impression of terror had been overcome, nothing could be more sublime than these awful sounds, which seemed like a warning of Etna not to pry too deeply into his secrets.

Dr. Judd, an American naturalist, who, in 1841, descended into the crater of Kilauea, on Mauna Loa, in Hawaii, well-nigh fell a victim to his curiosity. At that time the smallest of the two lava pools which boil at the

LAKE OF FIRE BY NIGHT.

bottom of that extraordinary pit appeared almost inactive, giving out only vapours, with an occasional jet of lava at its centre. Dr. Judd, considering the quiet favourable for dipping up some of the liquid with an iron ladle, descended for the purpose to a narrow ledge bordering the pool. While he was preparing to carry out his idea, his attention was excited by a sudden sinking of its surface; the next instant it began to rise, and then followed an explosion, throwing the lava higher than his head. He had scarcely escaped from his dangerous situation, the moment after, by the aid of a native, before the lava boiled up, covered the place where he stood, and, flowing out over the northern side, extended in a stream a mile wide to a distance of more than a mile and a half!

In extinct volcanoes, the picture of desolation originally shown by their craters has not seldom been changed into one of charming loveliness. Tall forest-trees cover the bottom of the Tofua crater in Upolu, one of the Samoan group; and in the same island, a circular lake of crystal purity, belted with a girdle of the richest green, has formed in the depth of the Lanuto crater.

The lakes of Averno near Naples, and of Bolsena, Bracciano, and Ronciglione, likewise fill the hollows of extinct craters, constituting scenes of surpassing beauty, rendered still more impressive by the remembrance of the stormy past which preceded their present epoch of tranquillity and peace. Mr. Mallett describes, with glowing colours, the singular beauty of the forest scenery around the two extinct craters of Mount Vultur in Apulia, which time has converted into two deep circular lakes.

"I descend amongst aged trunks and overarching boughs, and pass over masses of rounded lava-blocks and cemented lapilli. All is quietude; the soft breeze of a quiet winter's afternoon fans across the embosomed water, from the early wheat-fields and the furrowed acres of the opposite steep slopes, and brings the gentle ripple lapping amongst the roots of the old hazels at my feet.

"Off before me, and to my left, crowning the slope, are

the grey ruins of some ancient church or castle, and far above me to the right, nestled against the lava crags, behind and above it, standing out white and clear, I see the strong buttressed mass of the monastery of St. Michael. How hard it is to realise that this noble and lovely scene, full of every leafy beauty, was once the innermost bowl of a volcano; that every stone around me, now glorious in colour with moss and lichen, sedum and geranium, was once a glowing mass, vomited from out that fiery and undiscovered abyss, which these placid waters now bury in their secret chambers."

Extinct Crater of Haleakala.

The line of demarcation between active and extinct volcanoes is not easily drawn, as eruptions have sometimes taken place after such long intervals of repose as to warrant the belief that the vents from which they issued had long since been completely obliterated. Thus, though nearly six centuries have passed since the last eruption of Epomeo in the island of Ischia, we are not entitled to suppose it extinct, since nearly seventeen centuries elapsed between this last explosion and the one which preceded it. Since

the beginning of the fourteenth century Vesuvius also enjoyed a long rest of nearly three hundred years. During this time the crater got covered with grass and shrubs, oak and chestnut trees grew around it, and some warm pools of water alone reminded the visitor of the former condition of the mountain, when, suddenly, in December 1631, it resumed its ancient activity, and seven streams of lava at once burst forth from its subterranean furnaces.

While, in many volcanic districts, such as that of the Eifel on the left back of the Rhine, and of Auvergne in Central France, the once active subterranean fires have long since been extinguished, and no eruption of lava has been recorded during the whole period of the historic ages, new volcanoes, situated at a considerable distance from all previously active vents, have arisen from the bowels of the earth, almost within the memory of living man. From the era of the discovery of the New World to the middle of the last century, the country between the mountains Toluca and Colima, in Mexico, had remained undisturbed, and the space, now the site of Jorullo, which is one hundred miles distant from each of the above-mentioned volcanoes, was occupied by fertile fields of sugar-cane and indigo, and watered by two brooks. In the month of June 1769, hollow sounds of an alarming nature were heard, and earthquakes succeeded each other for two months, until, at the end of September, flames issued from the ground, and fragments of burning rocks were thrown to prodigious heights. Six volcanic cones, composed of scoriæ and fragmentary lava, were formed on the line of a chasm, running in the direction of N.E. to S.W. The least of the cones was 300 feet in height, and Jorullo, the central volcano, was elevated 1600 feet above the level of the plain. The ground where now, in Central America, Isalco towers in proud eminence, was formerly the seat of an estancia or cattle-estate. Towards the end of the year 1769 the inhabitants were frequently disturbed by subterranean rumblings and shocks, which constantly increased

in violence until, on February 23, 1770, the earth opened, and pouring out quantities of lava, ashes, and cinders, gave birth to a new volcanic mountain.

Besides those volcanic vents which are situated on the dry land, there are others which, hidden beneath the surface of the sea, reveal their existence by subaqueous eruptions. Columns of fire and smoke are seen to rise from the discoloured and agitated waters, and sometimes new islands are gradually piled up by the masses of scoriæ and ashes ejected from the mouth of the submarine volcano. In this manner the island of Sabrina rose from the bottom of the sea, near St. Michael's in the Azores, in the year 1811; and still more recently, in 1831, Graham's Island was formed in the Mediterranean, between the coast of Sicily and that projecting part of the African coast where ancient Carthage stood. Slight earthquake shocks preceded its appearance, then a column of water like a waterspout, 60 feet high and 800 yards in circumference, rose from the sea, and soon afterwards dense volumes of steam, which ascended to the height of 1800 feet. Then a small island, a few feet high, with a crater in its centre, ejecting volcanic matter, and immense columns of vapour, emerged from the agitated waters, and in a fortnight swelled to the ample proportions of a height of 200 feet, and a circumference of three miles. But both Sabrina and Graham's Island, being built of loose scoriæ, were soon corroded by the waves, and their last traces have long since disappeared under the surface of the ocean.

Near Pondicherry, in India; near Iceland, in the Atlantic Ocean; half a degree to the south of the equator in the prolongation of a line drawn from St. Helena to Ascension; near Juan Fernandez, &c., similar phenomena have occurred within the last hundred years, but probably nowhere on a grander scale than in the Aleutian Archipelago, where, about thirty miles to the north of Unalaska, near the isle of Umnack, a new island, now several thousand feet high and two or three miles in circumference, was formed in 1796. The whole bottom of the sea between this new

creation of the volcanic powers and Umnack has been raised by the eruptive throes which gave it birth; and where Cook freely sailed in 1778, numberless cliffs and reefs now obstruct the passage of the mariner.

The famous subaqueous volcano which, in the year 186 before the Christian era, began its series of historically recorded eruptions, by raising the islet of Hiera (the "Sacred") in the centre of the Bay of Santorin, opened two new vents in 1866. Amid a tremendous roar of steam and the shooting up of prodigious masses of rock and ashes, two islets were formed, which ultimately rose to the height of 60 and 200 feet. The eruption continued for many months, to the delight and wonder of the numerous geologists who came from all sides to witness the instructive spectacle. Thus, in many parts of the ocean, we see the submarine volcanic fires laying the foundations of new islands and archipelagoes, which, after repeated eruptions following each other in the course of ages, will probably, like Iceland, extend over a considerable space and become the seats of civilised man.

As a very considerable part of the globe has never yet been scientifically explored, it is of course impossible to determine the exact number of the extinct and active volcanoes which are scattered over its surface. Werner gives a list of 193 volcanoes, and Humboldt mentions 407, of which 225 are still in a state of activity. The newest computation of Dr. Fuchs, of Heidelberg,* increases the number to a total of 672, of which 270 are active. Future geographical discoveries will, no doubt, make further additions to the list, and show that at least through a thousand different vents the subterranean fires have, at various periods of the earth's history, piled up their cones of scoriæ and lava.

The volcanoes are very unequally distributed over the surface of the globe, for, while in some parts they are thickly clustered together in groups or rows, we find in

* "Die vulcanischen Erscheinungen der Erde." Leipzig, 1865.

other parts vast areas of land without the least sign of volcanic action.

An almost uninterrupted range of volcanoes extends in a sinuous line from the Gulf of Bengal, through the East Indian Archipelago, the Moluccas, the Philippines, Formosa, Japan, and the Kuriles, to Kamtschatka. This desolate peninsula is particularly remarkable for the energy of its subterranean fires, as Ermann mentions no less than twenty-one active volcanoes, ranged in two parallel lines throughout its whole length, and separated from each other by a central range of mountains, containing a large and unknown number of extinct craters.

In Java, where more than thirty volcanoes are more or less active, the furnaces of the subterranean world are still more concentrated and dreadful.

The immense mountain-chains which run parallel to the western coast of America are likewise crowned with numerous volcanic peaks. Chili alone has fourteen active volcanoes, Bolivia and Peru three, Quito eleven. In Central America we find twenty-one volcanoes, which are chiefly grouped near the Lake of Nicaragua, and to the west of the town of Guatemala.

The peninsula of Aljaska, and the chain of the Aleütes, possess no less than thirty-six volcanoes, scattered over a line about 700 miles long; and thus we find the eastern, western, and northern boundaries of the Pacific encircled with a girdle of volcanic vents, while the subterranean fires have left the western shores of the Atlantic comparatively undisturbed.

With the exception of Iceland, which is famous for the widely devastating eruptions of its burning mountains, the volcanic energies of Europe are at present limited to the submarine crater of Santorin, and to the small area of Etna, Vesuvius, and the Lipari Islands. But, situated in the centre of the ancient seats of civilisation, and for so many centuries the object of the naturalist's researches, of the traveller's curiosity, and of the poet's song, they surpass in renown all other volcanic regions in the world.

Most other volcanoes vent their fury over lands either so wild or so remote that the history of their eruptions almost sounds like a legend from another planet; but thousands of us have visited Etna and Vesuvius, and the explosion of their rage menaces towns and countries which classical remembrances have almost invested with the interest of home.

Some volcanoes are in a continual state of eruption. Isalco, born, as we have seen, in 1770, has remained ever since so active as to deserve the name of the Faro (light-house) of San Salvador. Its explosions occur regularly, at intervals of from ten to twenty minutes, and throw up a dense smoke and clouds of ashes and stones. These, as they fall, add to the height and bulk of the cone, which is now about 2500 feet high. For more than two thousand years the fires of Stromboli have never been extinct, nor has it ever failed to be a beacon to the mariner while sailing after nightfall through the Tyrrhenian Sea. Mr. Poulett Scrope, who visited Stromboli in 1820, and looked down from the edge of the crater into the mouth of the volcano, some 300 feet beneath him, found the phenomena precisely such as Spallanzani described them in 1788. "Two rude openings show themselves among the black chaotic rocks of scoriform lava which form the floor of the crater. One is, to appearance, empty, but from it there proceeds, at intervals of a few minutes, a rush of vapour, with a roaring sound, like that of a smelting furnace when the door is opened, but infinitely louder. It lasts about a minute. Within the other aperture, which is perhaps twenty feet in diameter, and but a few yards distant, may be distinctly perceived a body of molten matter, having a vivid glow even by day, approaching to that of white heat, which rises and falls at intervals of from ten to fifteen minutes. Each time that it reaches in its rise the lip of the orifice, it opens at the centre, like a great bubble bursting, and discharges upwards an explosive volume of dense vapour with a shower of fragments of incandescent lava and ragged scoriæ, which

rise to a height of several hundred feet above the lip of the crater."

The volcanoes of Masaya, near the lake of the same name in Nicaragua; of Sion, in the Moluccas; and of Tofua, in the Friendly Islands, are also, like Stromboli, in a state of permanent eruption. But far more commonly the volcanoes burst forth only from time to time in violent paroxysms, separated from each other by longer phases of moderate activity, during which their phenomena are confined to the exhalation of vapours and gases, sometimes also to the ejection of scoriæ or ashes; to the oscillations of lava rising or subsiding in the shaft of the crater, to the gentle outflow of small streams of lava from its eruptive cone, and to slight commotions of its border. A continual or periodical exhalation of steam and gases from the shaft of the crater or from chasms and fissures in its bottom, is the commonest phenomenon shown by an active volcano while in a state of tranquillity. Aqueous vapours compose the chief part of these exhalations, and along with other volatile substances, such as sulphuretted hydrogen, sulphurous acid, muriatic acid, and carbonic acid, form the steam-jets or *fumaroles*, which escape with a hissing or roaring noise from all the crevices and chasms of the crater, and, uniting as they ascend in a single vapour-cloud, ultimately compose the lofty column of steam which forms so conspicuous a feature in the picturesque beauty of Etna or Vesuvius. High on the summit of Mauna Loa, where all vegetation has long since ceased, the warm steam of the fumaroles gives rise to a splendid growth of ferns in crevices sheltered from the wind; and on the Island of Pantellaria, the shepherds, by laying brushwood before the fumaroles, condense the steam, and thus procure a supply of water for their goats.

The gentle fluctuations of lava in a crater while in a state of moderate activity are nowhere exhibited on a grander scale than in the pit of Kilauea on Mauna Loa. The mountain rises so gradually as almost to resemble a plain, and the crater appears like a vast gulf excavated in

its flanks. The traveller perceives his approach to it by a few small clouds of steam, rising from fissures not far from his path. While gazing for a second indication, he stands unexpectedly upon the brink of the pit. A vast amphitheatre seven miles and a half in circuit has opened to view. Beneath a grey rocky precipice of 650 feet, a narrow plain of hardened lava extends, like a vast gallery, around the whole interior. Within this gallery, below another similar precipice of 340 feet, lies the bottom, a wide plain of bare rock more than two miles in length. Here all is black monotonous desolation, excepting certain spots of a blood-red colour, which appear to be in constant yet gentle agitation.

When Professor Dana visited Kilauea (December 1840), he was surprised at the stillness of the scene. The incessant motion in the blood-red pools was like that of a caldron in constant ebullition. The lava in each boiled with such activity as to cause a rapid play of jets over its surface. One pool, the largest of the three then in action, was afterwards ascertained by survey to measure 1500 feet in one diameter and 1000 in another; and this whole area was boiling, as seemed from above, with nearly the mobility of water. Still all went on quietly. Not a whisper was heard from the fires below. White vapours rose in fleecy wreaths from the pools and numerous fissures, and above the large lake they collected into a broad canopy of clouds, not unlike the snowy heaps or cumuli that lie near the horizon on a clear day, though their fanciful shapes changed more rapidly.

On descending afterwards to the black ledge or gallery at the verge of the lower pit, a half-smothered gurgling sound was all that could be heard from the pools of lava. Occasionally, there was a report like that of musketry, which died away, and left the same murmuring sound, the stifled mutterings of a boiling fluid.

Such was the scene by day—awful, melancholy, dismal—but at night it assumed a character of indescribable sublimity. The large caldron, in place of its bloody glare,

now glowed with intense brilliancy, and the surface sparkled with shifting points of dazzling light, occasioned by the jets in constant play. The broad canopy of clouds above the pit, which seemed to rest on a column of wreaths and curling heaps of lighted vapour, and the amphitheatre of rocks around the lower depths, were brightly illuminated from the boiling lavas, while a lurid red tinged the distant parts of the enclosing walls, and threw their cavernous recesses into deeper shades of darkness. Over this scene of restless fires and glowing vapours, the heavens by contrast seemed unnaturally black, with only here and there a star, like a dim point of light.

A paroxysmal eruption is generally announced by the intensification of the phenomena above described. Slight earthquakes are felt in the neighbourhood of the volcano, and follow each other in more rapid succession and with greater violence as the catastrophe draws near. A deep noise like the rolling of thunder, or like the roar of distant artillery, is heard under the ground; the white steam from the crater ascends in denser clouds, which soon acquire a darker tinge; and now the bottom of the crater suddenly bursts with a terrific crash, and with the rapidity of lightning an immense column of black smoke shoots up into the air, and expanding at its upper end into a broad horizontal canopy, assumes a shape which has been compared with that of the Italian pine, the graceful tree of the South. As the column of smoke spreads over the sky, it obscures the light of the sun, and changes day into night. Along with the smoke, showers of glowing lava are cast high up into the air, and, rising like rockets, either fall back into the crater or rattle down the declivity of the cone.

At night the scene assumes a character of matchless grandeur, when the column of smoke—or, more properly speaking, of scoriæ, vapour, and impalpable dust—is illuminated by the vivid light of the lava glowing in the crater beneath. It then appears as an immense pillar of fire, rising with steady majesty in the midst of the uproar

of all the elements, and ever and anon traversed by flashes of still greater brilliancy from the masses of liquid lava hurled forth by the volcano.

The detonations which accompany an eruption are sometimes heard as single crashes, at others as a rolling thunder or as a continuous roaring. They are frequently audible at an astonishing distance, over areas of many thousand square miles, and with such violence that they may be supposed to proceed from the immediate neighbourhood. Thus, during the eruption of Cosiguina in Nicaragua, which took place in the year 1834, the detonations were heard as loud as a thunderstorm in the neighbourhood of Kingston in Jamaica, and even at Santa Fè de Bogota, which is a thousand miles distant from the volcano. With the increase of steam generated during an eruption, the quantity of ejected scoriæ likewise increases in an astonishing manner, so that the volcano's mouth resembles a constantly discharging mine of the most gigantic dimensions.

The stones and ashes projected during a volcanic eruption vary considerably in size, from blocks twelve or fifteen feet in diameter to the finest dust. Both their immense quantity, and the force with which they are hurled into the air, show the utter insignificance of the strength displayed by the most formidable engines invented by man when compared with elementary power. Huge blocks are shot forth, as from the cannon's mouth, to a perpendicular elevation of 6000 feet, and La Condamine relates that in 1533 Cotopaxi hurled stones of eight feet in diameter in an oblique direction to the distance of seven miles. The lighter scoriæ, carried far away by the winds, not seldom bury whole provinces under a deluge of sand and ashes; and their disastrous effects, spreading over an immense area, are frequently greater than those of the lava streams, whose destructive power is necessarily confined to a narrower space. To cite but a few examples, the rain of sand and ashes which in 1812 menaced the Island of St. Vincent with the fate of Pompeii, soon buried every trace of vege-

tation, and the affrighted planters and negroes fled to the town. But here also the black sand, along with many larger stones, fell rattling like hail upon the roofs of the houses, while at the same time a tremendous subterranean thunder increased the horrors of the scene. Even Barbadoes, though eighty miles from St. Vincent's, was covered with ashes. A black cloud, approaching from the sea, brought with it such pitchy darkness that in the rooms it was impossible to distinguish the windows, and a white pocket-handkerchief could not be seen at a distance of five inches.

The fall of ashes caused in April 1815 by the eruption of the Temboro, in Sumbawa, not only devastated the greater part of the island, but extended in a westerly direction to Java, and to the north, as far as Celebes, with such an intensity that it became perfectly dark at noon. The roofs of houses at the distance of forty miles were broken in by the weight of the ashes that fell upon them. To the west of Sumatra the surface of the sea was covered two feet deep with a layer of floating pumice or scoriæ, through which ships with difficulty forced their way.

By the terrific eruption of Cosiguina in the Gulf of Fonseca, in Central America, in 1835, all the ground within a radius of twenty-five miles was loaded with scoriæ to the depth of ten feet and upwards, while the lightest and finest ashes were carried by the winds to places more than 700 miles distant. Eight leagues to the southward of the crater they covered the ground to the depth of three yards and a half, destroying every sign of life. Thousands of cattle perished, their bodies being in many instances one mass of scorched flesh. Deer and other wild animals sought the towns for protection; birds and beasts were found suffocated in the ashes, and the neighbouring streams were polluted with dead fish.

When we consider the amazing quantity of stones and ashes rejected in these and similar instances by volcanic power, we cannot wonder that considerable mountains have frequently been piled up by one single eruption. Thus in

the Bay of Baiæ near Naples, Monte Nuovo, a hill 440 feet high, and with a base of more than a mile and a half in circumference, was formed, in less than twelve hours, on September 29, 1538; and near Bronte, on the slopes of Etna, a few days gave birth to Monte Minardo, which rises to the still more considerable height of 700 feet. It would be curious to calculate how many thousands of workmen, and what length of time, man would need to raise mounds like these, produced by an almost instantaneous effort of nature.

In other cases the expansive power of the elastic vapours, which cast up these prodigious masses from the bowels of the earth, is such as to blow to pieces the volcanic cone through which it seeks its vent.

In Quito there is an ancient tradition that Capac Urcu, which means "the chief," was once the highest volcano near the equator, being higher than Chimborazo, but at the beginning of the fifteenth century a prodigious eruption took place which broke it down. The fragments of trachyte, says Mr. Boussingault, which once formed the conical summit of this celebrated mountain, are at this day spread over the plain. On August 11, 1775, the Pepandajan, in Java, formerly one of the highest mountains of the island, broke out in eruption; the inhabitants of the country around prepared for flight, but, before they could escape, the greater part of its summit was shivered to pieces and covered the neighbourhood with its ruins, so that in the upper part of the Gurat Valley forty villages were completely buried. During the dreadful eruption of 1815, the Temboro, in Sumbawa, is said to have lost at least one-third of its height from the explosion of its summit, and similar instances are mentioned as having occurred among the volcanoes of Japan.

In the year 1638 a colossal cone called the Peak, in the Isle of Timor, one of the Moluccas, was entirely destroyed by a paroxysmal explosion. The whole mountain, which was before this continually active, and so high that its light was visible, it is said, three hundred miles off, was

blown up and replaced by a concavity now containing a lake.

Again, according to M. Moreau de Jonnes, in 1718, on March 6, 7, at St. Vincent's, one of the Leeward Isles, the shock of a terrific earthquake was felt, and clouds of ashes were driven into the air, with violent detonations, from a mountain situated at the eastern end of the island. When the eruption had ceased, it was found that the whole mountain had disappeared like the baseless fabric of a dream.

The disastrous effects of the showers of sand, pumice, and lapilli ejected by a volcanic eruption are increased by the transporting power of water. The aqueous vapours which are evolved so copiously from volcanic craters during eruptions, and often for a long time subsequently to the discharge of scoriæ and lava, are condensed as they ascend in the cold atmosphere surrounding the high volcanic peak; and the clouds thus formed, being in a state of high electrical tension, give rise to terrific thunderstorms. The lightning flashes in all directions from the black canopy overhanging the mountain, the perpetually rolling thunder adds its loud voice to the dreadful roar of the labouring volcano, while torrents of rain, sweeping along the light dust and scoriæ which they carry down with them from the air, or meet with on their way, produce currents of mud, often more dreaded than streams of lava, from the far greater velocity with which they move.

It not seldom happens that the eruptions of volcanoes rising above the limits of perpetual snow are preceded or accompanied by the rapid dissolution of the ice which clothes their summits or their sides, owing to the high temperature imparted to the whole mass of the mountain by the vast conflict raging within. Thus in January 1803 one single night sufficed to dissolve or sweep away the enormous bed of snow which in times of rest covers the steep cone of Cotopaxi (18,858 feet high), so that on the following morning the dark mountain, divested of its

brilliant robe, gave warning to the affrighted neighbourhood of the terrific scenes that were about to follow. The volcanoes of Iceland, which mostly rise in the midst of vast fields of perpetual ice, frequently exhibit this phenomenon. On October 17, 1758, the eruptive labouring of Kötliugia gave birth to three enormous torrents, which carried along with them such masses of glacier fragments, sand, and stones as to cover a space fifty miles long and twenty-five miles broad. Blocks of ice as large as houses, and partly bearing immense pieces of stone on their backs, were hurried along by the floods; and soon after the eruption took place with a terrific noise.

A very singular phenomenon sometimes occurs in the gigantic volcanoes of the Andes. By the infiltration of water into the crevices of the trachytic rock of which they are composed, the caverns situated at their declivities or at their foot are gradually changed into subterranean lakes or ponds, which frequently communicate by narrow apertures with the Alpine brooks of the highlands of Quito. The fish from these brooks live and multiply in the subterranean reservoirs thus formed, and when the earthquakes which precede every eruption of the Andes Chain shake the whole mass of the volcano, the caverns suddenly open and discharge enormous quantities of water, mud, and small fish.

When in the night between the 19th and 20th of June 1698, the summit of Carguairazo (18,000 feet high) was blown up, so that of the whole crater-rim but two enormous peaks remained, the inundated fields were covered, over a surface of nearly fifty square miles, with fluid tuff and clay-mud enveloping thousands of dead fish. Seven years before, the malignant fever which prevailed in the mountain town of Ibarra, to the north of Quito, was attributed to the effluvia arising from the putrid fish ejected by the volcano of Imbaburu.

Amidst all these terrible phenomena—the dreadful noise, the quaking of the earth, the ejection of stones and ashes —which, often continuing for weeks or months, shake the

deepest foundations of the volcano, fiery streams of liquid lava gush forth sooner or later as from a vase that is boiling over. Their appearance generally indicates the crisis of the subterranean revolution, for the rage of the elements, which until then had been constantly increasing, diminishes as soon as the torrent has found an outlet. The lava rarely issues from the summit crater of the mountain; much more frequently it flows from a lateral rent in the volcano's side, which, weakened and dislocated in its texture by repeated shocks, at length gives way to the immense pressure of the lava column boiling within. From the vast size of these eruptive rents, we may form some idea of the gigantic power of the forces which give them birth.

Thus during the great eruption of Etna in 1669, the south-east flank of the mountain was split open by an enormous rent twelve miles long, at the bottom of which incandescent lava was seen. The extreme length of the fissure which gave lateral issue to the lava of Kilauea in 1840 was twenty-five miles, as could distinctly be traced through the disturbance of the surface rocks above; and in the terrific eruption of Skaptar Jökull, which devastated the west coast of Iceland in 1783, lava gushed forth from several vents along a fissure of not less than 100 miles in length. In some cases the whole mass of the volcano has been cleft in two. Vesuvius was thus rent in October 1822 by an enormous fissure broken across its cone in a direction N.W. to S.E.

Here and there along the line of such a rent, cones of eruption are thrown up in succession at points where the gaseous matter obtains the freest access to the surface, and has power to force up lava and scoriæ. Few, indeed, if any, of the greater volcanic mountains are unattended by such minor elevations, clustering about its sides like the satellites of a planet. Professor Dana found Mauna Loa covered with numerous parasitic cones, and Mr. Darwin counted several thousands on one of the Gallapagos Islands. On the flanks of Etna, according to Professor Sartorius von Waltershausen, more than 700 of them are to be seen;

almost all possessing craters, and each marking the source of a current of lava. Though they appear but trifling irregularities when viewed from a distance as subordinate parts of so imposing and colossal a mountain, many of them would nevertheless be deemed hills of considerable height in almost any other region. The double hill near Nicolosi, called Monte Rossi, formed in 1669, is 450 feet high and two miles in circumference at its base; and Monte Minardo, near Bronte, on the east of the great volcano, is upwards of 700 feet in height.*

"On looking down from the lower borders of the desert region of Etna," says Sir Charles Lyell, "these minor volcanoes, which are most abundant in the woody region, present us with one of the most delightful and characteristic scenes in Europe. They afford every variety of height and size, and are arranged in beautiful and picturesque groups. However uniform they may appear when seen from the sea, or the plains below, nothing can be more diversified than their shape when we look from above into their craters, one side of which, as we have seen, is generally broken down. There are indeed few objects in nature more picturesque than a wooded volcanic crater. The cones situated in the higher parts of the forest zone are chiefly clothed with lofty pines, while those at a lower elevation are adorned with chestnuts, oaks, and beech-trees."

As the point where a lava-current finds a vent is often situated at a considerable distance below the surface of the liquid column in the internal chimney of the volcano, the pressure from above not seldom causes the lava to spout forth in a jet, until its level in the crater shaft has been reduced to that of the newly-formed orifice. Thus, when Vesuvius was rent by the dreadful paroxysmal eruption of 1794, the lava was seen to shoot up in magnificent fountains as it issued from the openings along the fissure.

Further on, the lava flows down the mountain's side according to the same laws which regulate the movements

* See p. 86.

of any other stream, whether of water, mud, or ice: more rapidly down an abrupt declivity, slower where the slope is more gradual; now accumulating in narrow ravines, then spreading out in plains; sometimes rushing in fiery cascades down precipices, and where insurmountable obstacles oppose its progress, not seldom breaking off into several branches, each of which pursues its independent course.

At the point where it issues, the lava flows in perfect solution, but, as its surface rapidly cools when exposed to the air, it soon gets covered with scoriæ, which are dashed over each other in wild confusion, by successive floods of liquid stone, so as to resemble a stormy sea covered with ice-blocks. But the liquefied stone not only hardens on its external surface; it also becomes solid below, where it touches the colder soil, so that the fluid lava literally moves along in a crust of scoriæ, which lengthens in the same proportion as the stream advances.

The movements of the lava-current are of course considerably retarded by the formation of scoriæ, so that, unless where a greater inclination of the soil gives it a new impulse, it flows slower and slower. Thus the lava stream which was ejected by Etna during the great eruption of 1669, performed the first thirteen Italian miles of its course in twenty days, or at the average rate of 162 feet per hour, but required no less than twenty-three days for the last two miles. While moving on, its surface was in general a mass of solid rock; and its mode of advancing, as is usual with lava streams, was by the occasional fissuring of the solid walls. Yet in spite of the tardiness of its progress, the inhabitants of Catania watched its advance with dismay, and rushed into the churches to invoke the aid of the Madonna and the Saints. One citizen only, a certain Baron Papalardo, relied more upon his own efforts than upon supernatural assistance, and set out with a party of fifty men, dressed in skins to protect them from the heat, and armed with iron crows and hooks for the purpose of breaking open one of the solid walls of scoriæ that flanked

the liquid current, so as to divert it from the menaced city. A passage was thus opened for a rivulet of melted matter, which flowed in the direction of Paterno; but the inhabitants of that town being alarmed for their safety, took up arms against Papalardo, whose fifty workmen would hardly have been able to cope with the powers of nature. Thus, slowly but irresistibly, the lava advanced up to the walls of Catania, which being formed of huge Cyclopean blocks, and no less than sixty feet high, at first stemmed the fiery stream. But the glowing floods, pressing against the rampart, rose higher and higher, and finally reaching its summit, rushed over it in fiery cataracts, and destroying part of the town, at length disgorged themselves into the sea, where they formed a not inconsiderable promontory.

A truly gigantic conflict might naturally be expected from the meeting of two such powerful and hostile bodies as fire and water. This, however, is by no means the case, for as soon as the lava enters the sea, the rapid evaporation of the water that comes into immediate contact with it accelerates the cooling of the surface and thickens the hard external crust to such a degree that very soon all communication is cut off between the water and the fiery mass. While the lava continues to advance from the land, the crust of scoriæ is prolonged in the same proportion, and should it be rent here and there, steam is at once developed with such violence as to prevent all further access of the water into the interior of the fissures. Thus Breislak informs us that, in 1794, the eruption of a lava stream into the Bay of Naples, near Torre del Greco, took place with the greatest tranquillity, so that he himself was able to observe the advancing of the lava into the sea while seated in a boat immediately near it, without being disturbed by explosions or any other violent phenomenon.

As the crust of scoriæ is so bad a conductor of heat, it occasions a very slow cooling and hardening in the interior of the lava stream, forming, as it were, a vessel in which the liquid fire can be retained and preserved for a

long time. When Elie de Beaumont visited the lava stream of Etna, nearly two years after its eruption in 1832, its interior was still so warm that he could not hold his finger in the hot steam issuing from its crevices. It has also been proved, on trustworthy evidence, that after twenty-five and thirty years, many lava streams of Etna still continued to emit heat and steam; and after twenty-one years it was possible to light a cigar in the crevices of the lava that issued from Jorullo in 1759.

Another extremely curious effect of the scoriæ being such bad conductors of heat is, that masses of snow will remain unmelted though a lava stream rolls over them. Thus, in 1787, the lava of Etna flowed over a large deposit of snow, which, however, was by no means fully liquefied, but remained for the greatest part entire, and gradually changed into a granular and solid mass of ice. This was traced in 1828, by the geologist Gemellaro, for a distance of several hundred feet under the lava, and most likely still reposes under it as in an ice-cellar. The cliffs which form the vast crater-ring of the Isle of Deception, in the extreme Southern Atlantic, are likewise composed of alternate layers of ice and lava. Probably in both these cases the ice-beds have been covered, before the lava flowed over them, by a rain of scoriæ and volcanic sand, which is so well known among the shepherds in the higher regions of Etna as a bad conductor of caloric, that, to obtain a supply of water for their herds during the summer, they cover some snow a few inches deep with volcanic sand, which entirely prevents the penetration of solar heat.

Most of the recent lava streams evolve from all their fissures and rents a quantity of vapour, so as to be dotted with innumerable fumaroles, and to exhibit, as they flow along, a smoking surface by day and a luminous one by night. At first these fumaroles are so impetuous that they frequently puff up the lava-crust around their orifices into little cones or hillocks, consisting of blocks of scoriæ irregularly piled up over each other, and from whose summit the vapours continue to ascend. As the mass

cools, they are naturally lessened in numbers and in power; but in 1803 Humboldt still saw fumaroles from twenty to thirty feet high rising from the small cones which covered by thousands the great lava stream of Jorullo of the year 1759.

The vast dimensions of single lava streams give proof of the enormous powers which forced them out of the bowels of the earth. The lava stream of Vesuvius which destroyed Torre del Greco in 1794, is 17,500 French feet long, and when it reached the town was more than 2000 feet wide and forty feet deep. While this mighty mass of molten stone, the volume of which has been reckoned at about 457 millions of cubic feet, was descending towards the sea, another stream, whose mass is computed at about one-half of that of the former, was flowing in the direction of Mauro. This single eruption has therefore furnished more than 685 millions of cubic feet of lava, equal to a cube of 882 feet, in which at least a dozen of the largest churches, palaces, and pyramids on earth might conveniently find room. If to the solid lava we add the astonishing quantities of scoriæ, sand, and ashes thrown out by this same eruption, we may form some idea of the masses of matter which were in this one instance ejected from the interior of the earth.

The volume of the lava stream which flowed from the volcano of the Isle of Bourbon in the year 1787 is estimated at 2526 millions of cubic feet; but even this astonishing ejection of molten stone is surpassed by that which took place during the eruption of Skaptar Jökull * in 1783, when the lava rolled on to a length of fifty miles, and, on reaching the plain, expanded into broad lakes, twelve and fifteen miles in diameter and a hundred feet deep.

In the great eruption of Mauna Loa, which commenced on the 30th of May 1840, the lava began to flow from a small pit-crater called Avare, about six miles from Kilauea.

* A detailed account of this eruption, one of the most dreadful on record, is given in "The Polar World," chap. vi. p. 81.

The light was seen at a distance, but, as there was no population in that direction, it was supposed to proceed from a jungle on fire. The next day another outbreak was perceived farther towards the coast, and general alarm prevailed among the natives, now aware of the impending catastrophe. Other openings followed, and by Monday the 1st of June the large flow had begun, which formed a continuous stream to the sea, which it reached on the 3rd. This flood issued from several fissures along its whole course, instead of being an overflow of lava from a single opening; it started from an elevation of 1244 feet, as determined by Captain Wilkes, at a point twenty-two miles distant from the first outbreak, and twelve from the shore. The scene of the flowing lava, as we are told by those who saw it, was indescribably magnificent. As it rolled along it swept away forests in its course, at times parting and enclosing islets of earth and shrubbery, and at other times undermining and bearing along masses of rock and vegetation on its surface. Finally, it plunged into the sea with loud detonations, and for three weeks continued to disgorge itself with little abatement.

The light which it emitted converted night into day over all eastern Hawaii. It was distinctly visible for more than one hundred miles at sea, and at the distance of forty miles fine print could be read at midnight. As previous to the eruption, the whole vast pit of Kilauea had been filled to the brim with the lava, which, bursting through the flanks of the mountain, thus found a vent towards the sea, we have some means of estimating the volume of the ejected masses in the actual cubic contents of the emptied pit. The area of the lower pit, as determined by the surveys of the American Exploring Expedition, is equal to 38,500,000 square feet. Multiplying this by 400 feet, the depth of the pit after the eruption, we have 15,400,000,000 cubic feet for the solid contents of the space occupied by lava before the eruption, and therefore the actual amount of the material which flowed from Kilauea. This is equivalent to a triangular range

800 feet high, two miles long, and over a mile wide at base.

Though generally symptoms of violent disturbance, such as shakings of the earth and loud thundering noises, precede the eruption of lava, yet this is not always the case. Thus the craters of Mount Kea have frequently disgorged their masses of molten stone without such accompanying phenomena. In 1843, when the volcano poured out a flood of lava, reaching for twenty-five miles down its side, all took place so quietly that persons at the foot of the mountain were unaware of it, except from the glare of light after the action had begun. Through its progress no sounds were heard below, nor did it cause any perceptible vibrations, except in the region of the outbreak, and there none of much violence.

The lava sometimes cools down with a smooth, solid, undulating surface, marked with rope-like lines and concentric folds, such as are seen on any densely viscid liquid if drawn out as it hardens; but much more frequently it appears as if shattered to a chaos of ruins. The fragments vary from one to hundreds of cubic feet, or from a half-bushel measure to a house of moderate size. They are of all shapes, often in angular blocks, and sometimes in slabs, and are horribly rough, having deep recesses everywhere among them. The traveller shudders as his path leads him over a lava field, thus bristling with myriads of spikes, where the least false step would precipitate him into the deep cavities, among the jagged surfaces and edges. This scene of horrid confusion often extends for miles in every direction, and, viewed from its central part, the whole horizon around is one wide waste of grey and black desolation, beyond the power of words to describe.

The breaking up of a lava field into chaotic masses evidently proceeds from a temporary cessation, either complete or partial, and a subsequent flow of a stream of lava. The surface cools and hardens as soon as the stream slackens; afterwards there is another heaving of the lava,

and an onward move, owing to a succeeding ejection or the removing of an obstacle, and the motion breaks up the hardened crust, piling the masses together, either in slabs or huge angular fragments, according to the thickness to which the crust had cooled. If the motion of a lava stream be quite slow, the cooling of the front of it may cause its cessation, thus damming it up and holding it back, till the pressure from gradual accumulation behind sweeps away the barrier. It then flows on again, carrying on its surface masses of the hardened crust—some, it may be, to sink and melt again, but the larger portion to remain as a field of clinkers. The breaking up of the ice of some streams in spring gives some idea of the manner in which the hardened masses of a lava field are piled up as it moves along; but to form a just idea of the greatness of the effect, the mind must bring before it a stream, not of the scanty limits of most rivers, but one, not unfrequently, of several miles in breadth: besides, in place of slabs of pure and clear ice, there should be substituted shaggy heaps of black scoriæ, and a depth or thickness of many yards in place of a few inches.

Where volcanic mud-streams have flooded the land, or a rain of ashes and light scoriæ has descended upon the soil, its fertility may soon be restored under the influence of a sunny sky; but as far as the lava reaches, a stony wilderness often remains for ages, particularly in the colder regions of the earth. Thus, though many of the lava fields of Iceland have existed long before the first Scandinavian colonists settled in the land, their surface is generally as naked as when they first issued from the volcano; and where signs of vegetation may be seen among their fragments, the eye finds nothing to relieve the horrid monotony of the scene but spare patches of lichen and mosses, or here and there some dwarf herb or shrub that hardly ventures to peep forth from the crevice in which it has found a shelter. But in a milder climate, such as that of Italy, and still more rapidly in the torrid zone, the horrid nakedness of a lava field undergoes a

more rapid transformation, provided a sufficient moisture favours the growth of plants. The rains promote the decomposition of the lava, and a rank vegetation succeeds, which in its turn assists the work of decomposition, and thus hastens the accumulation of soil. Ferns and grasses spring up in the nooks and crevices, and finally the vine or the taro flourish luxuriantly, for nothing can exceed the fertility of a disintegrated lava field.

Volcanoes have frequently been considered as safety-valves, which, by affording a vent to subterranean vapours, preserve the neighbouring regions from the far more disastrous and wide-spreading effects of earthquakes; and facts are not wanting which seem to justify this opinion. After the soil had trembled for a long time throughout the whole of Syria, in the Cyclades, and in Eubœa, the shocks suddenly ceased when, in the plains near Chalcis, a stream of "*glowing mud*" (lava from a crevice) issued from the bowels of the earth. Strabo, who relates this incident, adds that "since the craters of Etna have been opened, through which fire ascends, the land on the sea-coast is less subject to earthquakes than at the time when all vents on the surface were stopped up."

Before the earthquake which destroyed the town of Riobamba, the smoke of the volcano of Pasto, which is 200 miles distant, disappeared. The Neapolitans and Sicilians consider the eruptions of Vesuvius and Etna, or even a more lively activity of these volcanoes, as a certain preservative against devastating earthquakes, and we meet with the same belief among the inhabitants of Quito and Peru. But in many cases this fancied security has proved to be delusive, as very violent earthquakes have not seldom been found to accompany volcanic eruptions. The great Chilian earthquake of 1835 coincided with an eruption of Antuco; and the shocks which agitated all Kamtschatka and the long chain of the Kurilian Islands, in 1737, occurred simultaneously with an eruption of Klîutschewskaja Skopa.

Professor Dana doubts whether action so deep-seated as

that of the earthquake must be, can often find relief in the narrow channels of a volcano miles in length. He points out the example of Mauna Loa, where lavas are frequently poured out from the summit crater, at an elevation of more than 10,000 feet above Kilauea, so that the latter, notwithstanding its extent, the size of its great lakes of lava, and the freedom of the incessant ebullition, is not a safety-valve that can protect even its own immediate neighbourhood.

In his opinion volcanoes might more fitly be called indexes of danger. They point out those portions of the globe which are most subject to earthquakes, and are results of the same causes that render a country liable to such convulsions.

The phenomena attending an eruption can leave no doubt that below every active volcano a large subterranean cavity must exist in which melted lava accumulates. The partisans of the theory which supposes the earth to consist of a central fluid mass with a solid shell resting upon it, attribute the formation of volcanoes to rents or fissures in this crust through which the lava is cast forth; but the local development of heat by chemical action, or some other unknown cause, is quite sufficient to account for the existence of fiery lakes embedded in a solid mass, and which, though insignificant when compared with the surface of the globe, may still be large enough to produce volcanic phenomena on the grandest scale.

The cause of the reaction of such a reservoir against the surface of the earth must in all probability be sought for in the expansive force of steam; for when water, penetrating through crevices or porous strata, comes in contact with the heated subterranean mass, it is evident that the steam thus generated must press upon the lava, and, when formed in sufficient quantity, ultimately force it up the duct of the volcano. In other cases, we may suppose a continuous column of lava mixed with liquid water raised to a red-hot or white-hot temperature under the influence of pressure. A disturbance of equilibrium may first bring

on an eruption near the surface, by the expansion and conversion into gas of the entangled water, so as to lessen pressure. More and more steam would then be liberated, bringing up with it jets of liquid rock, and ultimately ejecting a continuous stream of lava. Its force being spent, a period of rest succeeds, until the conditions for a new outburst (accumulation of steam and melted rock) are obtained, and another cycle of similar changes is renewed. The important part which water plays in volcanic action is moreover sufficiently proved by the enormous quantity of steam which is poured forth during every eruption, or is constantly escaping in the fumaroles of a crater. The various gases (carbonic, muriatic, sulphurous) which are likewise exhaled by volcanoes may also have been rendered liquid by pressure at great depths, and may assist the action of water in causing eruptive outbursts. The great number of active volcanoes on sea-coasts and in islands likewise points to the agency of water in volcanic operations; and in the few cases where eruptive cones are situated far inland, their situation on the borders of a lake, or their cavernous and porous structure, accounts for the absorption of a quantity of atmospheric water, sufficient for the production of volcanic phenomena.

CHAPTER VII.

DESTRUCTION OF HERCULANEUM AND POMPEII.

State of Vesuvius before the eruption in the year A.D. 79—Spartacus—Premonitory earthquakes—Letter of Pliny the Younger to Tacitus, relating the death of his uncle, Pliny the Elder—Benevolence of the Emperor Titus—Herculaneum and Pompeii buried under a muddy alluvium—Herculaneum first discovered in 1713.

Of all the volcanic eruptions recorded in history there is none more celebrated than that which, on the 23rd of August, A.D. 79, buried the towns of Herculaneum and Pompeii under a deluge of mud and ashes. Many other eruptions have no doubt been on a grander scale, or may have spread ruin and desolation over a wider area, but never has volcano, awakening from the slumber of a thousand years, devastated a more smiling paradise than the fields of happy Campania, or buried more beautiful cities.

Before that terrible catastrophe, Mount Vesuvius, now constantly smoking, even in times of rest, had, ever since the first colonisation of South Italy by the Greeks, exhibited no signs of volcanic activity. Even tradition knew of no previous disturbance. No subterranean thunder, or sulphurous streams, or cast-up ashes, gave token of the fires slumbering beneath its basis; and the real nature of the apparently so peaceful mountain could only be conjectured from the similarity of its structure to other volcanoes, or from the ancient lava streams that furrowed its abrupt declivities. At that time also its shape was very different from its present form, for instead of two apices,

it exhibited, from a distance, the regular outlines of a sharply truncated cone. Plutarch relates that rough rock walls, piled round its summit, and overgrown with wild vines, enclosed the waste of the crater.

When, in 73 B.C., Spartacus, with seventy of his comrades, broke the fetters of an insupportable slavery, he found a secure retreat in this natural stronghold, which could only be scaled by a single narrow and difficult path. By degrees 10,000 fugitive slaves gathered round his standard, and Rome began to tremble for her safety. The prætor Clodius led an army against the rebels, and surrounded the mountain; but Spartacus caused ropes to be made of the branches of wild vines, by means of which he, with the boldest of his followers, was let down from the rocks, where they were supposed to be totally inaccessible, and, falling unawares upon the prætor, put his troops to flight and took his camp. The declivities of the mountain, thus become historically renowned, were covered with the richest fields and vineyards, and at its foot, along the beautiful Bay of Naples, lay the flourishing towns of Herculaneum and Pompeii, the seats of luxury and refinement. Who could, then, have imagined that this charming scene was so soon to be disturbed in so terrible a manner, and that the time was nigh when the ancient volcanic channels, from which, in unknown ages, lava streams and ashes had so frequently broken forth, were once more to be reopened? The first sign which announced the awakening energies of the volcano was an earthquake, which, in A.D. 63, devastated the fertile regions of Campania. From that time, to the crowning disaster of 79, slight tremors of the earth frequently occurred, until, finally, the dreadful eruption took place which Pliny the Younger so vividly describes in his celebrated letter to Tacitus.

"My uncle," says the Roman, "was at Misenum, where he commanded the fleet. On the 23rd of August, about one o'clock in the afternoon, my mother informed him that a cloud of an uncommon size and form was seen to arise. He had sunned himself (according to the custom of the

ERUPTION OF VESUVIUS, BAY OF NAPLES.

ancient Romans), and taken his usual cold bath, then dined, and studied. He asked for his sandals, and ascended an eminence, from which the wonderful phenomenon could be plainly seen. The spot from whence the cloud ascended, in a shape like that of an Italian pine-tree, could not be ascertained on account of the distance; its arising from Vesuvius only subsequently became known.

"In some parts it was white, in others black and spotted, from the ashes and stones which it carried along. To my uncle, being a learned man, the phenomenon seemed important, and worthy of a closer investigation. He ordered a light ship to be got ready, and left it to my option to accompany him. I answered that I preferred studying, and by chance he himself had given me something to write. He was on the point of leaving the house when he received a letter from Resina, the inhabitants of which, alarmed at the impending danger—the place lay at the foot of the mountain, and escape was only possible by sea—begged him to help them in their great distress. He now changed his plan, and executed as a hero the undertaking to which he had been prompted as a natural philosopher.

"He ordered the galleys of war to set sail, and embarked to bring help, not only to Resina, but to many other places along the coast, which, on account of its loveliness, was very densely peopled.

"He hastens to the spot from which others are taking flight, and steers in a direct line towards the seat of danger, so unconcerned as to dictate his observations upon all the events and changes of the catastrophe, as they passed before his eyes.

"Already ashes fell upon the ship, hotter and thicker on approaching, and also pumice and other stones blackened and burnt by fire. Suddenly a shallow bottom, and the masses ejected by the eruption, rendered the coast inaccessible. He hesitated for a moment whether he should sail back again, but, soon resolved, said to the steersman who advised him to do so, 'Fortune favours the bold; steer towards the villa of Pomponianus.' This friend

resided at Stabiæ, on the opposite side of the bay, where the danger, although as yet at some distance, was still within sight, and menacing enough. Pomponianus had therefore caused his effects to be conveyed on board a ship, intent on flight so soon as the contrary wind should have abated. As soon as my uncle, to whom it was very favourable, has landed, he embraces, consoles, encourages his terrified friend, takes a bath to relieve his fears by his own confidence, and dines after the bath with perfect composure, or, what is no less great, with a serene countenance.

"Meanwhile high columns of flame burst forth from Vesuvius in various places, their brilliancy being increased by the darkness of the night. My uncle, with the intention of relieving apprehension, said that they proceeded from the villas which, abandoned by their terrified proprietors and left a prey to the flames, were now burning in solitude. He then retired and slept soundly, for his attendants before the door heard him fetch his breath, which, on account of his corpulence, was deep and loud. But now the court, into which the room opened, became filled to such a height with ashes and pumice that by a longer delay he would not have been able to leave it. They awaken him, he rises, and greets Pomponianus and the others who had watched. They consult together, whether to remain in the house or to flee into the open air, for the ground trembled from the repeated and violent shocks of the earth, and seemed to reel backwards and forwards. On the other hand, they feared in the open air the falling of the pumice-stones and cinders. On comparing these two dangers, flight was chosen; and, as a protection against the shower of stones, they covered their heads with cushions. Everywhere else the day was already far advanced, but the blackest night still reigned at Stabiæ. Provided with torches, they resolved to seek the shore, in order to ascertain whether they could venture to embark, but the sea was found to be too wild and boisterous.

"My uncle now lay down upon a carpet, and asked for some cold water, of which he repeatedly drank. The flames

and their sulphurous odour drove away his companions, and forced him to rise. Leaning on two slaves, he tried to move, but immediately sank down again, suffocated, as I believe, by the dense smoke, and by the closing of his larynx, which was by nature weak, narrow, and subject to frequent spasms. On the third morning after his death the body was found without any marks of violence, covered with the clothes he had worn, and more like a person sleeping than a corpse."

Thus perished, in his fifty-sixth year, one of the greatest naturalists and noblest characters of ancient Rome, the philosopher to whom we are indebted for the first general description of the world—a work which, in spite of its numerous imperfections and errors, is one of the most interesting monuments of classical literature.

When the rage of the volcanic powers had subsided, the sun, now no longer obscured by clouds of ashes, shone upon a scene of utter desolation, where nature, embellished by art, had, but a few days before, appeared in all her loveliness. The mountain itself had changed its form, and rose with new peaks to the skies; a thick layer of stones and dust had settled with the curse of sterility on the fields; thousands of homeless wretches wandered about disconsolate, and three towns—Pompeii, Herculaneum, Stabiæ—had disappeared, to be brought to light again in a wonderful manner after the lapse of many centuries.

This great catastrophe gave the Emperor Titus a fine opportunity for displaying the benevolence which entitled him to be called "the delight of mankind." He immediately hastened to the scene of destruction, appointed guardians of consular rank to distribute among the needy survivors the property of those who had perished without heirs; and encouraged the weak-hearted, assisting them by liberal donations, until a no less terrible misfortune recalled him to Rome, where a fire, which laid almost half the town in ashes, was followed by a plague, which, for some time, daily swept away thousands.

It has often been asked how so many of the relics buried

in Herculaneum and Pompeii could have been so perfectly preserved as to form a Museum of the Past for the admiration and instruction of future ages. A stream of lava would undoubtedly have consumed everything on its fiery track, but, fortunately for posterity, it was not a flood of molten stone, but a current of mud, which overwhelmed the devoted cities. We learn from history that a heavy shower of sand, pumice, and lapilli was ejected from Vesuvius for eight successive days and nights, in the year 79, accompanied by violent rains, and thus all these volcanic matters were converted into mud-streams, which, rushing down the sides of the mountain, descended upon Herculaneum and Pompeii. This circumstance satisfactorily explains how the *interior* of the buildings, with all the underground vaults and cellars, was filled up, and how all the objects they contained could be as perfectly moulded as in a plaster cast by the muddy alluvium, which subsequently hardened into pumice tuff. Hence this wonderful preservation of paintings, which, shielded from the destructive influence of the atmosphere, still retained their original freshness of colour when again brought to light by a late generation; these rolls of papyrus which it has been found possible to decipher; this perfect cast of a woman's form, with a child in her arms!

No lava has flowed over Pompeii since that city was buried, but with Herculaneum the case is different. Although the substance which fills the interior of the buildings in that doomed city must have been introduced in a state of mud like that found in similar situations in Pompeii, yet the superincumbent mass differs wholly in composition and thickness.

Herculaneum was situated several miles nearer to the volcano, and has, therefore, been always more liable to be covered, not only by showers of ashes, but by alluvium and streams of lava. Accordingly, masses of both have accumulated on each other above the ancient site of the city, to a depth of nowhere less than 70, and in many places of 112 feet; while the depth of the bed of ashes under which

Pompeii lies buried, seldom exceeds 12 or 14 feet above the houses, and it is even said that the higher part of the amphitheatre always projected above the surface.

Yet, strange to say, Herculaneum, though far more profoundly hidden, was discovered before Pompeii, by the accidental circumstance that a well sunk in 1713 came right down upon the theatre where the statues of Hercules and Cleopatra were found. Many others were afterwards dug out and sent to France by the Prince of Elbœuf, who, having married a Neapolitan princess, became proprietor of the field under which the theatre lies buried. Further excavations were, however, forbidden by Government, and only resumed in 1736. But the difficulty of removing the large masses of lava accumulated above the city, and the circumstance of its partly lying under the modern towns of Portici and Resina, have confined the exploration of Herculaneum within narrow limits. The large theatre alone is open for inspection, and can be seen only by torchlight, so that its dark galleries, cut through the tuff, are but seldom visited by strangers; while no traveller leaves Naples without having wandered through the ruins of Pompeii, for Italy hardly affords a more interesting sight than that of these streets and forums, these theatres and temples, these houses and villas, which require but the presence of their ancient inhabitants to complete the picture of a Roman town, such as it was eighteen hundred years ago.

CHAPTER VIII.

GAS SPRINGS AND MUD VOLCANOES.

Carbonic acid springs—Grotto del Cane—The Valley of Death in Java—Exaggerated descriptions—Carburetted hydrogen springs—The Holy Fires of Baku—Description of the Temple—Mud volcanoes—The Macaluba in Sicily—Crimean mud volcanoes—Volcanic origin of mud volcanoes.

THE numerous gas springs which in many countries are evolved from an unknown depth, afford us a convincing proof that the remarkable chemical transformations of which we find so many traces in the past history of our planet are still perpetually taking place in many of the mysterious crevices and hollows of the earth-rind. In Auvergne, the Vivarrais, the Eifel, and along the whole basaltic range from the Rhine to the Riesengebirge in Silesia, carbonic acid gas is exhaled in incredible quantities from the vast laboratories of the subterranean world.

Professor Bischoff found that a single gas spring near Burgbrohl daily produced 5650 cubic feet of carbonic acid, a quantity amounting in the course of a year to no less than 262,000 lbs. in weight; and, according to Bromeis, the great Artesian spring at Nauheim evolves every minute 71 cubic feet of carbonic acid, equal to a weight of 5,000,000 lbs. annually. If from these two instances we judge of the produce of the many carbonic acid gas springs of Germany, and if we further extend our view to the rest of the world, in many parts of which carbonic

acid probably escapes in still greater quantities, we can form some idea of the geological importance of these springs, which also exercise no small influence upon the organic world. For the incalculable masses of carbonic acid which are thus constantly pouring from subterranean vents into the atmospheric ocean are again absorbed by millions of plants. They feed the forests and the fields; and thus these chemical changes, which are incessantly but imperceptibly modifying the earth-rind, ultimately tend to the advantage of man.

As a light dipped in carbonic acid gas is immediately extinguished, and every animal inhaling it is liable to instant suffocation, these properties are sometimes made use of for cruel experiments, for which, among others, the insignificant Grotto del Cane, in the kingdom of Naples —a cave or hole in the side of a mountain near the Lake Agnano—has become notorious. Some miserable dogs are thrust into the stratum of fixed air which covers the bottom of the hole, and are alternately almost choked and resuscitated to satisfy the idle curiosity of tourists. Their violent efforts to escape, when about to be plunged into the poisonous vapour, prove the horrible cruelty of the practice.

The carbonic acid springs in the glen of the Brohl, a small rivulet flowing into the Rhine, near Andernach, are turned to a better purpose, for the manufacture of white lead.

The famous "Valley of Death," or Poison Valley, in the Island of Java, is nothing more than a funnel-shaped hollow, measuring about 100 feet in diameter at the top, and with a bare space in its centre fifteen feet broad and long, which is frequently covered with a stratum of carbonic acid gas. The sides of the hollow, and even the bottom, with the exception of the above-mentioned naked spot, are everywhere clothed with shubbery, or even with forest trees.

The dead bodies of stags, tigers, wild boars, and birds are said to have been frequently found in the hollow; but

Dr. Junghuhn, the author of a classical work on Java, saw in 1838 but one human corpse lying on its back in the centre of the bare spot. It was still there in 1840, and but slightly decomposed. In 1845 it had been removed, most likely by some compassionate wanderers desirous of giving it a decent burial, for not the slightest trace of the skeleton remained. During the years 1838, 1840, and 1845 Junghuhn visited the Valley of Death no less than thirteen times. When he last saw it, the bodies of six wild hogs were lying at the bottom, all more or less in a state of putrefaction. The crows that were feasting upon their remains proved that a descent might be effected without danger, for, on seeing them hopping about on the naked soil, even the Javanese entered the circle without hesitation. Not a single trace of carbonic acid was to be perceived, not even when the bold naturalist stretched himself out upon the ground and drew his breath in the crevices and rents with which it was furrowed. Probably the gas never rises more than three feet above the level of the soil, as at this height a luxuriant vegetation begins.

This simple description of an accurate observer forms a strange contrast to the gross exaggeration of other travellers, whose accounts, copied in many hand-books, have puffed up a phenomenon hardly superior to that of the Grotto del Cane into something like an eighth wonder of the world. Loudon, who in July 1830 visited the Pakamaran (as the natives call the pit), swells its dimensions to a vast crater about half a mile in circumference, thickly strewn with skeletons of men, tigers, game, and birds of all kinds; and another recent traveller goes so far as to give it an extent of twenty miles.

Next to carbonic acid, but of far less general occurrence, carburetted hydrogen, which gives rise to the wonderful phenomenon of fiery springs, is the gas most frequently evolved by volcanic spiracles.

Near Pietra Mala, between Bologna and Florence, on a spot about twelve feet in diameter, several flames rise

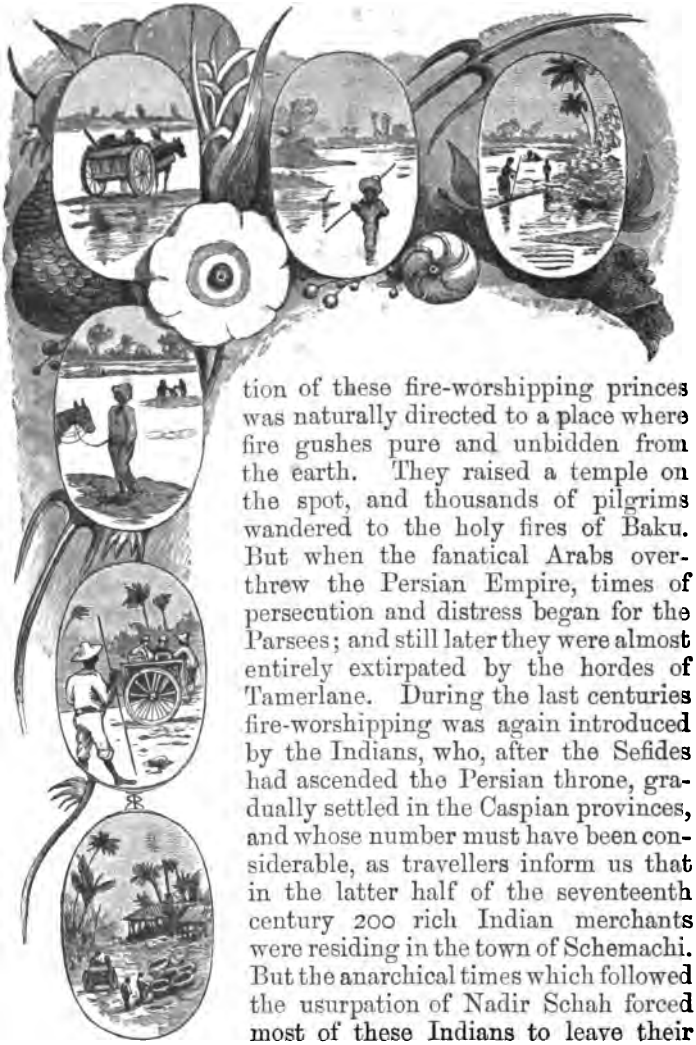
from the earth, the largest of which ascends to a height of five feet, and is seen burning at night with a pale yellow flame, while its minor satellites around are blue tipped with white. No doubt many a terrible legend is attached to this infernal spectacle. Near Barigazzo, between Modena and Pistoja, near the ruins of Velleji, and in many other parts of the volcanic region of the Apennines, similar flames gush out of the ground. The neat little town of Fredonia, in the State of New York, on the eastern shore of Lake Erie, is lighted by natural springs of carburetted hydrogen, which, being led into a gasometer, feed the seventy or eighty lamps of the town. The thrifty and practical Chinese, who have preceded us in so many useful discoveries, have for centuries made a like use of the many gaseous emanations in the provinces of Yunnan, Szutschuan, Kuangsi, and Schansi, by leading the inflammable air in pipes, wherever they want it for lighting or cooking.

But there is no place in the world more remarkable for its burning springs than Baku, on the western coast of the Caspian Sea, where the holy and eternal fires are worshipped by the pious Parsees as the special symbol of the Almighty.

Like most of the cloisters and convents of the Orient, which are exposed to the incursions of plundering hordes, Aleschga, the temple dedicated to the worship of fire, is a fortified square enclosing a large courtyard, and capable of being defended from the terraced roof. The outer wall forms at the same time the back of the cells, which front the yard. Over the entrance gate, which is situated to the north, rises a high bastion or tower, serving as an additional defence, from the summit of which the visitor enjoys after sunset the fantastic view of the flames which, untarnished by smoke, rise on all sides from rents and crevices in the neighbouring steppe, and wave their bright summits to and fro like tongues of fire. In the centre of the court stands a square tower supported by four columns, and enclosing a basin-like excavation, three or four feet

in diameter, into which the gas is conducted by a pipe from sources beyond the walls of the temple. Four chimneys at the four corners of the tower are fed in a similar manner. From the centre of the tower rises a trident, called *Thirsul*. The Parsees relate that the Devil once got possession of the earth, and reigned with despotic fury. But man in his distress prayed to the Almighty, and an angel came down and planted this identical trident in the earth as a token that the dominion of his Satanic Majesty had ceased. Round the court are twenty-two cells, like those of a Catholic convent. They are very small, and, with the exception of a ragged rug, wholly without furniture; but each of them is provided with a gaspipe, which can be opened or closed at pleasure, and furnishes light and warmth to the inmate. Near the temple a well has been dug fifty feet deep, in which the gas accumulates in larger quantities. Koch ("Wanderungen im Oriente," 1843–44) tells us that he here enjoyed a sight more wonderful and surprising than any he had ever witnessed before. A carpet was spread over the mouth of the well to prevent the gas from escaping. After a few minutes, a priest seized a bundle of brushwood, in which a piece of burning paper had been stuck, and flung it into the well, after quickly removing the carpet. The strangers had previously been warned to keep at some distance, and the priest and his assistants likewise ran off as fast as they could. About half a minute after the firebrand had been cast into the pit, a terrific explosion took place, and a vast column of fire, in the shape of an inverted cone (from the gas spreading out as soon as it emerges from the pit), ascended to the skies.

How long the fires of Baku may have been burning is unknown, but it is very probable that they did not exist before the Christian era. No Greek or Roman author mentions them, and it is not before the tenth century that Arab writers take notice of Baku and its wonders. When the Sassanides restored the religion of Zoroaster, the atten-



Pitch Lakes, Trinidad.

tion of these fire-worshipping princes was naturally directed to a place where fire gushes pure and unbidden from the earth. They raised a temple on the spot, and thousands of pilgrims wandered to the holy fires of Baku. But when the fanatical Arabs overthrew the Persian Empire, times of persecution and distress began for the Parsees; and still later they were almost entirely extirpated by the hordes of Tamerlane. During the last centuries fire-worshipping was again introduced by the Indians, who, after the Sefides had ascended the Persian throne, gradually settled in the Caspian provinces, and whose number must have been considerable, as travellers inform us that in the latter half of the seventeenth century 200 rich Indian merchants were residing in the town of Schemachi. But the anarchical times which followed the usurpation of Nadir Schah forced most of these Indians to leave their adopted country, and since then only

solitary pilgrims have found their way to Baku. But the number even of these is constantly diminishing, although the Russians, to whom the sanctuary now belongs, allow them full freedom of access. When Koch was at Baku, he found there only five Indians from Mooltan, whither the majority would gladly have returned, had they but possessed the necessary means. Their squalid appearance and tattered raiment formed the strongest imaginable contrast to the splendour of the element they worshipped. Among them was a Fakir, who had made a vow constantly to remain in the same position absorbed in religious contemplation, and who for sixteen years had never moved from the spot.

The burning springs gush out not only from the ground near the temple and in other parts of the peninsula of Abscheron, but even from the bottom of the neighbouring Caspian Sea; and as Sir Charles Lyell saw carburetted hydrogen rise in countless bubbles through the crystal waters above the falls of the Niagara, and shoot up in bright flames at the approach of a light, so Dr. Abich mentions a spot in the Gulf of Baku where the inflammable gas issues with such force, and in so great a quantity, from the bottom, which is there three fathoms deep, that a small boat is in danger of being overturned when coming too near it.

As gas springs most frequently occur in districts which have been the former seats of volcanic action, and as similar exhalations often arise from still active craters, they are supposed by many geologists to be the last remaining traces of an expiring volcanic energy. Bischoff considers the carbonic acid of the German gas springs to be developed by the decomposition of carbonate of lime by volcanic heat or heated water.

A phenomenon which is sometimes found connected with gas springs is that of the mud volcanoes, which may be described as cones of a ductile, unctuous clay, formed by the continued evolution of a sulphurous and inflammable gas, spurting up waves and lumps of liquid mud. These

remarkable caldrons are found in many parts of the world, in the Island of Milo, in Italy, in Iceland, in India, about 120 miles from the mouths of the Indus, on the coast of Arracan, in Birmah, in Java, Columbia, Nicaragua, and Trinidad; but probably nowhere on a grander scale than at either extremity of the chain of the Caucasus, towards the Caspian on the east and the Sea of Azof on the west, where in the peninsula of Taman, and on the opposite

Mud Volcanoes of Trinidad.

coast of the Crimea, near Kertsch, vast numbers of mud volcanoes are scattered, some of them 250 feet high. Their operations have apparently been going on for countless ages, and have covered a great extent of land with their products.

The Macaluba, in Sicily, which owes its name to the Arabs, is the mud volcano most anciently known. It is mentioned by Plato in his "Phædon," and has been described by Strabo. It is situated five miles to the north of Girgenti, on a hill of a conical shape, truncated at the top, and 150

feet high. The summit is a plain half a mile round, and the whole surface is covered with thick mud. The depth of the mud, which is supposed to be immense, is unknown. There is not the slightest appearance of vegetation upon it. In the rainy season the mud is much softened; the surface is even, and there is a general ebullition over it, which is accompanied with a very sensible rumbling noise. In the dry season the mud acquires greater consistency, but its motion still goes on. The plain assumes a form somewhat convex; a number of little cones are thrown up, which rarely rise to the height of two feet. Each of them has a crater, where black mud is seen in constant agitation, and incessantly emitting bubbles of air. With these the mud insensibly rises, and as soon as the crater is full of it, it disgorges. The residue sinks, and the cone has a free crater, until a new emission takes place.

Such is the ordinary state of the Macaluba; but from time to time the hill becomes subject to alarming convulsions. Slight earthquake shocks are felt at a distance of two or three miles, accompanied with internal noises resembling thunder. These increase for several days, and are followed at last by a prodigious spout of mud, earth, and stones, which rises two or three hundred feet in the air.

Similar paroxysmal explosions have been observed in the Caucasian mud volcanoes. In February 1794, the Obu, in the peninsula of Taman, had an eruption accompanied with a dreadful noise, and an earthquake which radiated from the cone, and was felt as far as Ekaterinodor, at a distance of fifty-five leagues. At the beginning of the eruption flames were seen, which rose to a prodigious height, and lasted about half an hour. At the same time dense clouds of smoke escaped from the crater, and mud and stones were cast up to the height of 3000 feet. Six streams of mud, the largest of which was half a mile long, flowed from the volcano, and their volume is said to have been equal to twenty-two millions of cubic feet.

Violent eruptive symptoms accompanied the formation

of a new mud volcano in the vicinity of Baku on the Caspian. On November 27, 1827, flames blazed up to an extraordinary height for three hours, and continued for twenty hours more to rise about three feet above a crater from which mud was ejected. At another point in the same district, where flames issued, fragments of rock, of large size, were hurled up into the air and scattered around.

The phenomena exhibited by the Macaluba and other mud caldrons are certainly very distinct from those of true volcanoes, since no scoriæ or lava or heated matters of any kind are sent forth, the mud being described as cold when emitted, although the gas, whose violent escape throws it up, is sometimes ignited. Hence geologists commonly regard these phenomena as entirely distinct from the volcanic, and ascribe their origin to chemical action going on at no great depth beneath the surface, among the constituents of certain stratified matters; while other scientific authorities declare them to be as much connected with internal igneous agency as any other eruptive phenomena. Their occurrence in districts not remote from the sites of vast volcanic disturbance, and their occasional violent paroxysms, certainly afford much support to this view, and show that it is probably the same power, in different degrees of energy, which casts up the mud of the Macaluba and pours forth the lava streams of Cotopaxi.

CHAPTER IX.

EARTHQUAKES.

Extent of misery inflicted by great earthquakes—Earthquake regions—Earthquakes in England—Great number of earthquakes—Vertical and undulatory shocks—Warnings of earthquakes—Sounds attending earthquakes—Remarkable displacements of objects—Extent and force of seismic wave motion—Effects of earthquakes on the sea—Enormous waves on coasts—Oscillations of the ocean—Fissures, landslips, and shattering falls of rock caused by earthquakes—Causes of earthquakes—Probable depth of Focus—Opinions of Sir Charles Lyell and Mr. Poulett Scrope—Impressions produced on man and animals by earthquakes.

Of all the destructive agencies of nature there is none to equal the earthquake. The hurricane is comparatively weak in its fury; the volcanic eruption generally confines its rage to the neighbourhood of the labouring mountain, but a great earthquake may cover a whole land with ruins.

The terrible subterranean revolution which convulsed all Asia Minor and Syria, in the reign of Tiberius, destroyed twelve celebrated cities in a single night. The sun, which on setting had gilded their temples and palaces with his parting rays, beheld them prostrate on the following morning.

In A.D. 115 Antioch was the centre of a great commotion. The city was full of soldiers under Trajan; heavy thunder, excessive winds, and subterranean noises were heard; the earth shook, the houses fell; the cries of

people buried in the ruins passed unheeded. The emperor leaped from a window, while mountains were broken and thrown down, and rivers disappeared, and were replaced by others in a new situation. Four centuries later (May 20, 526) the same doomed city was totally subverted by an earthquake, when it is reported that 250,000 persons perished.

Similar catastrophes, in which thousands and thousands of victims were suddenly destroyed, have frequently occurred in Peru and Chili, in the West Indies and Central America, in the Moluccas and Java, in the countries bordering on the Mediterranean and the Red Sea; but a bare mention of the loss of life conveys but a faint idea of the extent of misery inflicted by one of those great earthquakes which mark with an ominous shade many large tracts of the earth's surface.

We must picture to ourselves the slow lingering death which is the fate of many—some buried alive, others burnt in the fire which almost invariably bursts out in a city where hundreds of dwellings have suddenly been laid prostrate—the numbers who escaped with loss of limbs or serious bodily injuries, and the surviving multitude, suddenly reduced to penury and want.

In the Calabrian earthquake of 1783, it is supposed that about a fourth part of the inhabitants of Polistena and of some other towns were buried alive, and might have been saved had there been no want of hands; but in so general a calamity, where each was occupied with his own misfortunes or those of his family, help could seldom be procured. "It frequently happened," says Sir Charles Lyell, "that persons in search of those most dear to them could hear their moans, could recognise their voices, were certain of the exact spot where they lay buried beneath their feet, yet could afford them no succour. The piled mass resisted all their strength, and rendered their efforts of no avail. At Terranuova four Augustin monks, who had taken refuge in a vaulted sacristy, the arch of which continued to support a vast pile of ruins, made their cries

heard for the space of four days. One only of the brethren of the whole convent was saved, and of what avail was his strength to remove the enormous weight of rubbish which had overwhelmed his companions? He heard their voices die away gradually, and when afterwards their four corpses were disinterred, they were found clasped in each others' arms.

Affecting narratives are preserved of mothers saved after the fifth, sixth, and even seventh day of their interment, when their infants or children had perished with hunger. In his work on the great Neapolitan earthquake of 1857, Mr. Mallet, from innumerable narratives of personal peril and sad adventure, selects the distressing case of a noble family of Monte Murro, as affording a vivid picture of the terrors of an earthquake night. Don Andrea del Fino, the owner of one of the few houses in the city which escaped total destruction, was with his wife in bed, his daughter sleeping in an adjacent chamber on the principal floor. At the first shock his wife, who was awake, leaped from bed, and immediately after, a mass of the vaulting above came down, and buried her sleeping husband. At the same moment, the vault above their daughter's room fell in upon her. From the light and hollow construction of the vaults neither was at once killed. The signora escaped by leaping from the front window, she scarcely knew how. For more than two hours she wandered, unnoticed, amongst the mass of terrified survivors in the streets, before she could obtain aid from her own tenants and dependants to extricate her husband. They got him out after more than eighteen hours' entombment — alive, indeed, but maimed and lame for life. His daughter was dead. As he lay longing despairingly for release from the rubbish, which a second shock, an hour after the first, had so shaken and closed in around him that he could scarcely breathe, he heard, but a few feet off, her agonising cries and groans grow fainter and fainter, until at last they died away. His wife, to whose devotion his own life was owing, had escaped unhurt.

Unfortunately man too often vies with the brute forces of nature to increase the horrors of a great earthquake. As the arm of the law is paralysed by the general panic, thieves and ruffians are not slow to avail themselves of their opportunity. Thus, in the Calabrian catastrophe of 1783, nothing could be more atrocious than the conduct of the peasants, who abandoned the farms and flocked in great numbers into the towns—not to rescue their countrymen from a lingering death, but to plunder. They dashed through the streets amid tottering walls and clouds of dust, trampling beneath their feet the bodies of the wounded and half buried, and often stripping them, while yet living, of their clothes.

From the vast ruin and misery they entail, it is evident that where earthquakes are frequent, there can never be perfect security of property even under the best government; and as the fruits collected by the labour of many years may be lost in an instant, the progress of civilisation and national wealth must necessarily be retarded.

"Earthquakes alone," says Mr. Darwin, "are sufficient to destroy the prosperity of any country. If beneath England the now inert subterranean forces should exert those powers which most assuredly in former geological ages they have exerted, how completely would the entire condition of the land be changed! What would become of the lofty houses, thickly-packed cities, great manufactories, the beautiful public and private edifices? If the new period of disturbance were first to commence by some great earthquake in the dead of the night, how terrific would be the carnage! England would at once be bankrupt; all papers, records, and accounts would from that moment be lost. Government, being unable to collect the taxes, and failing to maintain its authority, the hand of violence and rapine would remain uncontrolled. In every large town famine would go forth, pestilence and death following in its train.

Fortunately the experience of many ages shows that the

regions subject to these terrible catastrophes are confined to a comparatively small part of the surface of the globe. Thus Southern Italy and Sicily; the tract embracing the Canaries, the Azores, Portugal, and Morocco; Asia Minor, Syria, and the Caucasus; the Arabian shore of the Red Sea; the East Indian Archipelago; the West Indies, Nicaragua, Quito, Peru, and Chili, are particularly liable to destructive shocks.

But beyond these limits slighter earthquakes are of far more common occurrence than is generally supposed, and probably they leave no part of the world entirely undisturbed. From the year 1821 to 1830 no less than 115 earthquakes have been felt to the north of the Alps, and since the year 1089, 225 are cited in the annals of England. Some of these earthquakes seem to have but just stopped at the point when a slight increase of their force would have covered the land with ruins. In 1574, on the 26th of February, between five and six in the evening, an earthquake was felt at York, Worcester, Hereford, Gloucester, and Bristol. Norton Chapel was filled with worshippers; they were nearly all overthrown, and fled in terror, thinking that the dead were unearthed or that the chapel was falling. Six years later, on the 6th of April, at 6 P.M., all England was thrown into consternation. The great bell at Westminster began to toll; the students at the Temple started up from table and rushed into the street, knives in hand; a part of the Temple Church fell, and stones dropped from St. Paul's. Two stones fell in Christ's Church, and crushed two persons. In rushing out of the church many were lamed, and there was a shower of chimneys in the streets. At Sandwich, the occurrence was marked by the violence of the sea, which made ships run foul of each other; and at Dover a part of the fortifications fell with the rock which supported it.

On the 6th October 1863, a movement, though gentle when compared to the preceding instances, was felt from the English Channel to the Mersey, and from Hereford to

Leamington and Oxford. The Malvern range was about the centre of the area, as it has often been before. Even in alluvial Holland, six or eight slight earthquakes have been felt during the last century. The industrious researches of Kluge show that, during the eight years from 1850 to 1857, no less than 4620 earthquakes—a great proportion of which (509) fell to the share of Southern Europe—have been noticed in both hemispheres; and when we remember that a very considerable part of the globe is still either totally unknown or removed by the barbarous condition of its inhabitants from all intercourse with the scientific world, and that, consequently, the above list must necessarily be incomplete, it is very probable that not a day passes without some agitation of the surface of the earth in some place or other.

A violent earthquake almost always consists of several shocks following each other in rapid succession. Sometimes they are preceded by slighter vibrations; at other times they suddenly convulse the land without any previous notice. In most instances, each shock lasts but a few seconds; but this is enough to ruin the work of ages. Three violent commotions within five minutes destroyed the town of Caracas on March 26, 1812; and the earthquake which, in 1692, desolated Jamaica, lasted but three minutes. On January 11, 1839, two shocks within thirty seconds covered Martinique, and the whole range of the Lesser Antilles, with ruins. But a violent earthquake, though itself but of short duration, is generally followed by a series of secondary shocks, which are repeated at gradual widening intervals and with decreasing energy, so that if these subsequent tremors be taken into account, it may often be said to last for weeks or even months. Thus, to cite but one instance, the earthquake of October 21, 1766, destroyed the whole town of Cumana in a few minutes, but during the following fourteen months the earth was in a constant vibratory motion, and scarce an hour passed without a shock being felt.

In countries where earthquakes are comparatively rare

(for instance in the South of Europe), the belief is very general that oppressive heat, stillness of the air, and a misty horizon, are always forerunners of the phenomenon. But this popular opinion is not confirmed by the experience of trustworthy observers, who have lived for years in countries such as Cumana, Quito, Peru, and Chili, where the ground trembles frequently and violently. Humboldt experienced earthquakes during every state of the weather, serene and dry, rainy and stormy.

Brute animals, being more sensitive than men of the slightest movement of the earth, are said to evince extraordinary alarm, and it has been often observed that even the dull hog shows symptoms of uneasiness previous to the shock. During the great Neapolitan earthquake of 1857 an unusual halo-light was seen in the sky before, and not long after, the shock. Mr. Mallet was at first inclined to look upon this notion as a superstitious tale; but, finding it widely diffused in a country where communication is bad and news travel slowly, no longer doubted that it was founded on fact. Conjectures would be useless as to its nature, but future observation directed to the point may determine whether some sort of auroral light may emanate from the vast depths of rock formation under the enormous tensions and compressions that must precede the final crash and rupture; or whether volcanic action, going on in the unseen depths below, may give rise to powerful disturbances of electric equilibrium, and hence to the development of light; just as from volcanic mountains in eruption lightnings continually flash from the huge volumes of steam and floating ashes above the crater. Humboldt is also of opinion that, though in general the revolutions which take place below the surface of the earth are not announced beforehand by any meteorological process, or a peculiar appearance of the sky, it is not improbable that during violent shocks some change may occur in the condition of the atmosphere. Thus, during the earthquake in the Piedmontese valleys of Pelis and Clusson, great alterations were observed in the electric

tension of the atmosphere without any appearance of a thunderstorm.

Earthquakes are generally attended with sounds, sometimes like the howling of a storm, or the rumbling of subterranean thunder; at others like the clashing of iron chains, or as if a number of heavily laden waggons were rolling rapidly over the pavement, or as if enormous masses of glass were suddenly shivered to pieces. As solid bodies are excellent conductors of sound (burnt clay, for instance, propagating it ten or twelve times more rapidly than the air), the subterranean noise may be heard at a vast distance from the primary seat of the earthquake. In Caracas, in the grass-plains of Calabozo, and on the banks of the Rio Apure, which falls into the Orinoco, a dreadful thunder-like sound was everywhere heard on April 30, 1812, without any simultaneous trembling of the earth, at the time when, at the distance of 158 geographical miles, the volcano of St. Vincent, in the Lesser Antilles, was pouring out of its crater a mighty lava stream. This was, according to distance, as if an eruption of Vesuvius were heard in the North of France. In the year 1744, during the great eruption of the volcano Cotopaxi, a subterranean noise like the firing of cannon was heard at Honda on the Magdalena river. But the crater of Cotopaxi is 17,000 feet higher than Honda, and both points, situated at a distance of 109 geographical miles, are moreover separated by the colossal mountain masses of Quito, Pasto, and Popayan, and by numberless ravines and deep valleys. The sound was certainly transmitted, not through the air, but through the earth, and must have proceeded from a very considerable depth.

But noise is not the necessary attendant of an earthquake, for many instances are known in which the most violent shocks have been completely noiseless. No subterranean sounds were heard during the terrific earthquake which destroyed Riobamba on February 4, 1797, and the same circumstance is mentioned in the narratives of many of the Chilian earthquakes.

The phenomenon of sound, when unaccompanied by any perceptible vibration, makes a peculiarly deep impression on the mind, even of those who have long inhabited a country subject to frequent earthquakes. They tremble at the idea of the catastrophe which may follow. A remarkable instance of a long protracted noise without any trembling of the earth occurred in 1784, at the wealthy mining town of Guanaxuato in Mexico, where the rolling of subterranean thunder, with now and then a louder crash, was heard for more than a month, without the slightest shock, either on the surface of the earth, or in the neighbouring silver mines, which are 1500 feet deep. The noise was confined to a small space, so that a few miles from the town it was no longer audible. Never before had this phenomenon been known to occur in the Mexican highlands, nor has it been repeated since.

Earthquake shocks are either vertical or undulatory. A vertical shock, which is felt immediately above the seat or focus of the subterranean disturbance, causes a movement up and down. Like an exploding mine, it frequently jerks movable bodies high up into the air. Thus, during the great earthquake of Riobamba, the bodies of many of the inhabitants were thrown upon the hill of La Culla, which rises to the height of several hundred feet at the other side of the Lican torrent; and during the earthquake of Chili in 1837, a large mast, planted thirty feet deep in the ground at Fort San Carlos, and propped with iron bars, was thrown upwards, so that a round hole remained behind.

Although to the inhabitants of a shaken district the undulatory wave or vibration of an earthquake appears to radiate horizontally outwards from the spot on the surface where it is first felt, the force does not really operate in a horizontal direction, like a wave caused by a pebble on the surface of a pond; for at every point, except that immediately above the focus of the shock, it comes up obliquely from below, causing the ground to move forwards and then backwards in a more or less horizontal direction. As a

ship, yielding to the oscillatory movements of the waves, alternately inclines to one side or the other, so, during the more violent undulations of the soil, the objects on its surface are momentarily moved from their vertical position, and often considerably inclined towards the horizon. Thus during the great earthquake which convulsed the valley of the Mississippi in 1811–12, Mr. Bringier, an engineer of New Orleans, who was on horseback near New Madrid, where some of the severest shocks were experienced, saw the trees bend as the wave-motion of the earthquake passed under them, and immediately afterwards recover their position. The transit of the wave through the woods was marked by the crash of countless branches, first heard on one side and then on the other. It must have been awful to see the giants of the forest thus move to and fro like a corn-field agitated by the wind!

Very remarkable displacements of objects are not seldom caused by earthquakes, such as the rotation of the blocks of columns or the turning of statues on their pedestals.

At Lima, which, owing to its repeated destructions by earthquakes, is properly a city of ruins, Professor Dana saw two obelisks with the upper stone on each displaced and turned round on its axis about fifteen degrees in a direction from north to east. These rotations by earthquakes have been attributed by some authors to an actual rotatory movement in the earthquake vibration; but it has lately been shown by Mr. Mallet that this hypothesis is untenable and unnecessary, as a simple vibration back and forth is all that is required to produce a rotatory motion in the stone of a column, provided that stone be attached below more strongly on one side of the centre than on the opposite.

The wave-motion of an earthquake sometimes spreads over enormous spaces. The shocks of the earthquake of New Granada, which took place in the night from the 16th to the 17th of June 1826, were noticed over a surface of 750,000 square miles. The earthquake of Valdivia (Feb-

ruary 20, 1835) was felt southwards on the distant island of Chiloe to the north as far as Copiapo, in Mendoza to the east of the Andes, and on the Island of Juan Fernandez, 300 miles from the coast. Supposing these effects to have taken place at corresponding distances in Europe, all the land would have trembled from the North Sea to the Mediterranean, and from Ireland to the centre of France.

It is evident that the extent and force of the wave-motion of an earthquake must in a great measure depend upon the nature of the rocks through which it is transmitted. It will vibrate more easily through solid homogeneous masses, while in alluvial deposits, or in a soil composed of sand and loose conglomerate, its undulations will be propagated irregularly, and its effects be far more destructive. This is particularly the case where the alluvial deposits repose on a substratum of hard rock. Thus the devastations of the Calabrian earthquake of 1783 were most apparent in the plain of Oppido, in those parts where the newer tertiary strata rest upon granite. The earthquake wave generally follows the direction of mountain chains, and but rarely crosses them. The great Chilian earthquakes, which often propagate their vibrations to distances of many hundred miles along the western foot of the Andes, remain unfelt on their eastern border; while the earthquakes along the shores of Venezuela, Caracas, and New Granada rarely transmit their vibrations beyond the high mountain chains which run parallel with the coast. This is probably due to the numerous dislocations, rents, and caverns which are produced by the elevation of the mountain chains, and necessarily serve as barriers to the propagation of the earthquake wave.

Severe earthquakes are not seldom accompanied by a violent agitation of the sea. First, at the instant of the shock, the water swells high up on the beach with a gentle motion, and then as quietly recedes; secondly, some time afterwards the whole body of the sea retires

from the coast, and then returns in waves of overwhelming force. The first movement seems to be an immediate consequence of the earthquake affecting differently a fluid and a solid, so that their respective levels are slightly deranged; but the second is a far more important phenomenon. "Some authors," says Mr. Darwin, "have attempted to explain it by supposing that the sea retains its level, while the land oscillates upwards; but surely the water close to the land, even on a rather steep coast, would partake of the motion of the bottom; moreover, similar movements of the sea have occurred at islands far distant from the chief line of disturbance. I suspect (but the subject is a very obscure one) that a wave, however produced, *first draws the water from the shore* on which it is advancing to break. I have observed that this happens with the little waves from the paddles of a steamboat. From the great wave not immediately following the earthquake, but sometimes after the interval of even half an hour, and from distant islands being affected similarly with the coasts near the focus of the disturbance, it appears that the wave first rises in the offing, and, as this is of general occurrence, the cause must be general. I suspect we must look to the line where the less disturbed waters of the deep ocean join the water nearer the coast which has partaken of the movements of the land, as the place where the great wave is first generated; it would also appear that the wave is larger or smaller according to the extent of shoal water which has been agitated together with the bottom on which it rested."

The following examples sufficiently prove that no storm, however violent, is capable of raising such prodigious waves as an earthquake.

In the year 1692 the town of Kingston in Jamaica was almost totally destroyed by a huge earthquake wave. A frigate which lay in port was carried forward over the houses, and stranded in the middle of the town. In his "Principles of Geology," Sir Charles Lyell relates that,

during the Calabrian earthquake of 1783, the Prince of Scilla had persuaded a great part of his vassals to betake themselves to their fishing-boats for safety, and he himself had gone on board. On the night of February 5, when some of the people were sleeping in the boats, and others on a level plain slightly elevated above the sea, the earth rocked, and large masses of rock were thrown down with a dreadful crash upon the plain. Immediately afterwards the sea, rising more than twenty feet above the level of this low tract, rolled foaming over it and swept away the multitude. It then retreated, but soon rushed back again with greater violence, bringing back with it some of the bodies it had carried away. At the same time every boat was sunk or dashed against the beach, and some of them were swept far inland. The aged prince was killed, with 1430 of his people.

After the earthquake which devastated the town of Lima on the 28th of October 1746, the sea rose on the evening of the same day eighty feet above its usual level in the neighbouring Bay of Callao, overwhelmed the town, and destroyed nearly all the inhabitants. Of the twenty-three ships which were lying in the harbour at the time, nineteen immediately sank, while the four others were thrown upon the land at a distance of nearly a league.

Shortly after the shock which desolated Chili on the 20th of February 1835, a great wave was seen from the distance of three or four miles, approaching in the middle of the Bay of Talcahuano with a smooth outline, but tearing up cottages and trees along the shore, as it swept onwards with irresistible force. At the head of the bay it broke in a fearful line of white breakers, which rushed up to a height of twenty-three vertical feet above the highest spring tides. Their force must have been prodigious, for at the Fort a cannon with its carriage, estimated at four tons in weight, was moved fifteen feet inwards. The whole coast was strewed over with timber and furniture, as if a thousand ships had been wrecked. As Mr. Darwin

walked along the shore, he observed that numerous fragments of rock, which, from the marine productions adhering to them, must recently have been lying in deep water, had been cast up high on the beach. One of these was six feet long, three broad, and two thick.

During the dreadful earthquake which in 1868 raised the strip of land at the western foot of the Andes from Iburra in Ecuador to Iquique in Peru, 1200 miles in length, the receding sea uncovered the bay at Iquique to the depth of four fathoms, and then, returning in an immense wave, a mass of dark blue water, forty feet high, rushed over the already ruined city, and swept away every trace of what had been a town. One spectator, seeing the whole surface of the sea rise like a mountain, ran for his life to the Pampa. The waves overtook him. Fighting with the dark water, amidst wreck and ruin of every kind, carried back into the bay, and again thrown back to the Pampa, wounded and half-naked, he crept for safety into a hole of the sand, and waited sadly for the dawn. At Arica, the British Vice-Consul, alarmed at the first shock, rushed out of the house with his family, and made for the high ground, in just terror of the expected sea-wave. Through the ruined town, amidst dead and dying, half stifled with dust, they reached rising ground, and, looking back, saw a dreadful sequel—the sea rushed in and left not a vestige remaining of the lower part of Arica. Six vessels were lost in the bay, or tossed over rocks and houses; an American gunboat was whirled away from her moorings, and laid, without a broken spar or tarnished flag, high and dry on the sand-hills, a quarter of a mile from the sea.

As might be expected from the movable nature of water, the wave-motion of earthquakes is frequently propagated to surprising distances over the sea. The Chilian earthquake of 1835 produced oscillations of the ocean that made themselves felt on the Sandwich Islands, at a distance of 5000 nautical miles. On Mauai, the sea retreated 120 feet, and then suddenly returned with a tremendous wave that swept away the trees and houses on the beach. In

Hawaii, a large congregation had assembled for divine service near Byron's Bay. Suddenly the water began to sink, so that soon a great part of the harbour was laid dry. The spectators hurried to the shore to admire the astonishing spectacle, when a wave, rising twenty feet above the usual tide-mark, inundated the land, destroyed sixty-six huts, and drowned eleven of the islanders, though the best swimmers in the world. So far from its starting-point did the South American earthquake seek its victims. Fifteen hours and a half after the great earthquake of Arica (1868), the water-wave undulating over the vast Pacific was felt at Chatham Islands, a distance of 6300 miles, and an hour later at New Zealand.

The enormous powers which come into action during a great earthquake show themselves not only in the destruction of edifices and the widespread ruin so produced, but in the changes which they effect in the configuration of the soil. Wherever masses of earth rest loosely upon a sloping surface of subjacent rock, or where steep mountain crests overlie wet and unctuous beds of shale, or where the rock itself is composed of incoherent material, or where river-banks are formed of precipitous masses of clays, or where the corroding waters have undermined the ground, the violent commotion caused by an earthquake cannot fail to produce landslips, fissures, and falls of rock. In 1571, on the 17th of February, the ground opened all at once at the "Wonder," near Putley, not far from Marcle in Herefordshire; and a large part of the sloping surface of the hill—twenty-six acres, it is said—descended with the trees and sheep-folds, and continued in motion from Saturday to Monday, masses of ground being turned round through half a circle in their descent. This was a great landslip, said to have been occasioned by an earthquake.

Earth-fissures were formerly supposed to be occasioned by a *stretching* of the ground, occasioned by the wavy nature of the shocks; but Mr. Mallet has shown that no earthquake wave can possibly produce any such stretch-

ing, and considers them as cases of small and incipient landslips caused by the shaking downwards of a loose mass. His own observations left no doubt in his mind that the descriptions, given by the Neapolitan Academy in their Historical Account of the Earthquake of 1783, of the earth-fissures therein produced, and designated constantly by the pompous term "voragines," are gross exaggerations; and that the well-known Jamaica earth-fissures, that were said to have opened and closed with the wave, and to have *bitten people in two*, must be regarded as audacious fables.

"The vulgar mind, filled from infancy with superstitious terrors as to 'the things under the earth,' is seized at once by the notion of these fissures of profound and fabulous depth with fire and vapour of smoke issuing from within their murky abysses; but they should cease to belong to science."

Enormous landslips are sometimes occasioned by earthquakes, but their extent depends less upon the power and energy of the shock than upon the conditions of unstable equilibrium presented by great masses of loose material, through the configuration of the country. In consequence of landslips or dislodgments of large masses of rock, alterations in the flow or distribution of the waters frequently take place. Thus, brooks or rivers are not seldom dammed, and temporary ponds or lakes created.

Permanent elevations of the land have been observed after some earthquakes. Thus, after the violent shocks of November 19, 1822, a great part of the coast of Chili was found to be raised several feet above its previous level; and after the great earthquake which occurred in New Zealand in the night of January 23, 1855, a large tract of land was found to be permanently upraised from one to nine feet. Before the shock there had been no room to pass between the sea and the base of a perpendicular cliff called Muka-Muka, except for a short time at low water, and the herdsmen were obliged to wait for low tide in order to drive their cattle past the cliff. But

immediately after the upheaval, a gently sloping raised beach, more than 100 feet wide, was laid dry, affording ample space at all states of the tide for the passage of man and beast.

These permanent elevations have often been attributed to the immediate agency of earthquakes; but Mr. Mallet proves this assumption to be a fallacy, as the impulse of the earthquake wave even right above the focus is utterly incapable of raising the level of the land by a height much more than instrumentally appreciable, and there is not the least evidence that any part even of this elevation is permanent. That earthquakes occur along with, and as part of, a train of other circumstances which do produce permanent elevation occasionally, and that earthquakes are probably always the signals that the forces producing elevation are operative, is another matter, with which that erroneous or loosely expressed view should not be confounded.

The causes of earthquake are still hidden in obscurity, and probably will ever remain so, as these violent convulsions originate at depths far below the reach of human observation. Mr. Mallet came to the conclusion that the depth of the original Calabrian shock in 1857 did not exceed seven or eight miles, and deduces from all the facts known as to the movements of earthquakes, that the subterranean points where the shocks originate perhaps never exceed thirty geographical miles, so that, even supposing the central nucleus of the earth to be fluid, they cannot possibly be due to the reaction of the internal ocean of molten stone upon the solid shell with which it is enveloped, but must have their seat within the latter. The existence of reservoirs of fused matter at various depths in the solid earth-rind is quite sufficient to account for all seismic and volcanic phenomena; for it is evident that whenever rain-water, or the waters of the sea percolating through rocks, gain access to these subterranean lakes of molten stone, steam must be generated, the pressure of which will in many cases rend and dislocate the incumbent masses.

"During such movements," says Sir Charles Lyell, "fissures may be formed and injected with gaseous or fluid matter, which may sometimes fail to reach the surface, while at other times it may be expelled through volcanic vents, stufas, and hot springs. When the strain on the rocks has caused them to split, or the roofs of pre-existing fissures or caverns have been made to fall in, vibratory jars will be produced and propagated in all directions, like waves of sound through the crust of the earth, with varying velocity, according to the violence of the original shock, and the density or elasticity of the substance through which they pass. They will travel, for example, faster through granite than through limestone, and more rapidly through the latter than through wet clay, but the rate will be uniform through the same homogeneous medium."

According to Mr. Poulett Scrope, the originating cause of the earthquake must be sought in the expansion of some deeply-seated mass of mineral matter, owing to augmentation of temperature or diminution of pressure. By this expansive force the solid rocks above are suddenly rent asunder, and whether below the sea or not, their violent disruption produces a jarring vibration, which is propagated on either side through their continuous masses in undulatory pulsations.

Some geologists are of opinion that earthquakes are frequently the result of the subsiding, sinking in, or cracking of subterranean cavern roofs, in consequence of the pressure of the superincumbent rocks. Small local earthquakes may be explained by this theory; but terrible convulsions which shake a whole continent evidently proceed from a far more formidable cause, and are more satisfactorily explained by the agency of subterranean heat and elastic vapours.

If, even during an ordinary storm, the black clouds, the howling of the wind, the flashes of lightning, and the loud claps of thunder, strike men and brutes with fear, we may naturally expect to see terror carried to its highest

pitch by so dreadful a phenomenon as an earthquake. All creatures living or burrowing under the earth—rats, mice, moles, snakes—hastily creep forth from their subterranean abodes, though many no doubt are gripped and suffocated by the suddenly-moved soil before they can effect their escape; the crocodile, generally silent, like our little lizards, rushes out of the river and runs bellowing into the woods; the hogs show symptoms of uneasiness; the horses tremble; the oxen huddle together; and the fowls run about with discordant cries. On man, the phenomenon makes a peculiarly deep impression.

"A bad earthquake," says Mr. Darwin, "at once destroys our oldest associations. The earth, the very emblem of solidity, has moved beneath our feet like a thin crust over a fluid. One second of time has created in the mind a strange idea of insecurity, which hours of reflection would not have produced." We can no longer trust the soil on which we stand, and feel ourselves completely at the mercy of some unknown destructive power, which at any moment, without forewarning, can destroy our property or our lives. But as first impressions are always the deepest, so habit renders man callous even to the terrors of an ordinary earthquake. In countries where slight shocks are of frequent occurrence, almost every vestige of fear vanishes from the minds of the natives, or of the strangers whom a long residence has familiarised with the phenomenon.

On the rainless coast of Peru, thunderstorms and hail are unknown. The thunder of the storm is there replaced by the thunder which accompanies the earthquake. But the frequent repetition of this subterranean tumult, and the general belief that dangerous shocks occur only twice or thrice in the course of a century, produce in Lima so great an indifference towards slighter oscillations of the soil, that they hardly attract more attention than a hail-storm in Northern Europe.

CHAPTER X.

THE GREAT EARTHQUAKE OF LISBON.*

A dreadful All Saints' Day—The victims of a minute—Report of an eye-witness—Conflagration—Banditti—Pombal brings chaos into order—Intrigues of the Jesuits—Damages caused by the earthquake in other places—At Cadiz—In Barbary—Widespread alarm—Remarks of Goethe on the earthquake.

HISTORY exhibits few catastrophes more terrible than that which was caused by the great earthquake which, on November 1, 1755, levelled the town of Lisbon to the dust. On other occasions, such as that of a siege, a famine, or a plague, calamity approaches by degrees, giving its victims time to measure its growth, and preparing them, as it were, to sustain an increasing weight of misery; but here destruction fell upon the devoted city with the rapidity of a flash of lightning.

A bright sun shone over Lisbon on that fatal morning. The weather was as mild and beautiful as on a fine summer's day in England, when, about forty minutes past nine in the morning, an earthquake shock, followed almost immediately by another and another, brought down convents, churches, palaces, and houses, in one common ruin, and at a very moderate computation, occasioned the loss of 60,000 lives. "The shocking sight of the dead bodies," says an eye-witness of the scene, "together with the shrieks and cries of those who were half buried in

* See frontispiece.

the ruins, exceeds all description; for the fear and consternation were so great that the most resolute person durst not stay a moment to remove a few stones off the friend he loved most, though many might have been saved by so doing; but nothing was thought of but self-preservation. Getting into open places, and into the middle of streets, was the most probable security. Such as were in the upper stories of houses were, in general, more fortunate than those who attempted to escape by the doors, for they were buried under the ruins with the greatest part of the foot passengers; such as were in equipages escaped best, though their cattle and drivers suffered severely; but those lost in houses and the streets are very unequal in number to those that were buried in the ruins of churches; for as it was a day of great devotion, and the time of celebrating mass, all the churches in the city were vastly crowded; and the number of churches here exceeds that of both London and Westminster; and as the steeples are built high, they mostly fell with the roof of the church, and the stones are so large that few escaped." *

Many of those who were not crushed or disabled by the falling buildings fled to the Tagus, vainly hoping that they might find there the safety which they had lost on land. For, soon after the shock, the sea also came rushing in like a torrent, though against wind and tide, and rising in an enormous wave, overflowed its banks, devouring all it met on its destructive path. Many large vessels sank at once; others, torn from their anchors, disappeared in the vortex, or, striking against each other, were shattered to pieces. A fine new stone quay, where about three thousand persons had assembled for safety, slipped into the river, and every one was lost; nor did so much as a single body appear afterwards.

Had the misery ended here, it might in some degree have admitted of redress; for, though lives could not be

* Philosophical Transactions, vol. xlix., part i., p. 404.

restored, yet a great part of the immense riches that were in the ruins might have been recovered; but a new calamity soon put an end to such hopes; for, in about two hours after the shock, fires broke out in three different parts of the city, caused by the goods and the kitchen fires being all jumbled together. About this time also, a fresh gale suddenly springing up, made the fire rage with such violence that, at the end of three days, the greatest part of the city was reduced to ashes. What the earthquake had spared fell a prey to the fire, and the flames consumed thousands of mutilated victims, who, incapable of flight, lay half buried in the ruins.

According to a popular report, which, true or not, shows the hatred in which the Holy Office was held, the Inquisition was the first building that fell down, and probably more than one inquisitor, who, in his lifetime, had sent scores of Jews or heretics to the stake, was now, in his turn, burnt alive.

As if the unshackled elements were not sufficient agents of destruction, the prisons also cast forth their lawless denizens, and a host of malefactors, rejoicing in the public calamity which paralysed the arm of justice, added rapine and murder to the miseries of the city.

More than 60,000 persons are supposed to have perished in Lisbon from all these various causes. The total loss of property was estimated at fifty millions of dollars—an enormous sum for a small country, and in times when money was far more valuable than at present. A few shocks sufficed to destroy the treasures accumulated by the savings of many generations.

The royal family was at this time residing in the small palace of Belem, about a league out of town, and thus escaped being buried among the ruins of the capital—a fortunate occurrence in the midst of so many misfortunes: for the anarchy that must have ensued from the destruction of all authority would have filled the cup of misery to the brim. As it was, Government seemed utterly incapable of contending with a disaster of such colossal proportions.

"What is to be done?" said the helpless king to his minister Carvalho, Marquis of Pombal, who, on entering the council-chamber, found his sovereign vainly seeking for advice among his weeping and irresolute courtiers: "how can we alleviate the chastisement which divine justice has imposed upon us?" "Sire! by burying the dead and taking care of the living," was the ready answer of the great statesman, whose noble bearing and confident mien at once restored the king's courage. From that moment José bestowed a boundless confidence upon Pombal. Without losing a single moment, the minister, invested with full powers, threw himself into a carriage, and hastened with all speed to the scene of destruction. Wherever his presence was most needed, there was he sure to be found. For several days and nights he never left his carriage, whence, incessantly active in his efforts to reduce chaos to order, he issued no less than two hundred decrees, all bearing the stamp of a master-mind. Troops from the provinces were summoned in all haste, and concentrated round the capital, which no one was allowed to leave without permission, so that the robbers who had enriched themselves with the plunder of palaces and churches were unable to escape with their spoil.

In all his numerous ordinances Carvalho neglected none of the details necessary for ensuring their practical utility, writing many of them on his knees with a pencil, and sending them, without loss of time, to the various officers charged with their execution. His wise regulations for ensuring a speedy supply and a regular distribution of provisions averted famine. Great fears were entertained of pestilential disorders in consequence of the putrid exhalations of so many corpses which it was impossible to bury. To prevent this additional misfortune, Carvalho induced the Patriarch to give orders that the bodies of the dead should be cast into the sea, with only such religious ceremonies as circumstances permitted.

But the Jesuits, the mortal enemies of the enlightened minister, did not lose this opportunity of intriguing against

him, and openly ascribed the catastrophe to the wrath of God against an impious Government. Thus Pombal had not only to cope with the disastrous effects of the earthquake, but also with the venomous attacks of hypocritical bigots, in spite of whose clamours he interdicted all public processions and devotional exercises that were calculated still further to inflame the excited minds of the populace.

Though Lisbon was the chief sufferer from the great earthquake of 1755, the shocks which destroyed the capital of Portugal proved disastrous in many other places, and vibrated far and wide over a considerable portion of the globe. St. Ubes was nearly swallowed up by the sudden rising of the sea. At Cadiz the shocks were so violent that the water in the cisterns washed backwards and forwards so as to make a great froth upon it. No damage was done, on account of the excessive strength of the buildings; but about an hour after, an immense wave, at least 60 feet higher than common, was seen approaching from the sea. It broke against the west part of the town, which is very rocky, and where, fortunately, the cliffs abated a great deal of its force. At last it burst upon the walls, destroyed part of the fortifications, and swept away huge pieces of cannon. The strong causeway which connects the town with the Island of Leon, was utterly destroyed, and more than fifty people drowned that were on it at the time.

In Seville a number of houses were thrown down, and the bells were set a-ringing in Malaga. In Italy, Germany, and France, in Holland, and in Sweden, in Great Britain and in Ireland, the lakes and rivers were violently agitated. The water in Loch Lomond rose suddenly and violently against its banks, so that a large stone lying at some distance from the shore, in shallow water, was moved from its place and carried to dry land, leaving a deep furrow in the ground along which it had moved. At Kinsale, in Ireland, a great body of water suddenly burst into the harbour, and with such violence that it broke the cables of

two vessels, each moored with two anchors, and of several boats which lay near the town. The vessels were whirled round several times by an eddy formed in the water, and then hurried back again with the same rapidity as before. London was shaken, the Midland Counties disturbed, and one high cliff in Yorkshire threw down its half-separated rocks. At Töplitz, in Bohemia, between eleven and twelve o'clock, the mineral waters increased so much in quantity that all the baths ran over. About half an hour before, the spring grew turpid, and flowed muddy, and having stopped entirely for nearly a minute, broke forth again with prodigious violence, driving before it a considerable quantity of reddish ochre. After this, it became clear, and flowed as pure as before, but supplying more water than usual, and that hotter and more impregnated with its medicinal substances.

In Barbary, the earthquake was felt nearly as severely as in Portugal. Great part of the city of Algiers was destroyed; at Fez, Mequinez, and Morocco, many houses were thrown down, and numbers of persons were buried in the ruins. At Tangiers and Sallee the waters rushed into the streets with great violence, and when they retired they left behind them a great quantity of fish.

Ships sailing on the distant Atlantic received such violent concussions that it seemed as if they had struck upon a rock, and even America was disturbed.

At the Island of Antigua the sea rose to such a height as had never been known before, and at Barbadoes a tremendous wave overflowed the wharfs and rushed into the streets. The remote Canadian lakes were seen to ebb and flow in an extraordinary manner, and the Red Indian hunter felt the last expiring pulsations of the great terrestrial shock which a few hours before had overthrown the distant capital of Portugal.

Such were the extraordinary effects of this terrible earthquake, which extended over a space of not less than four millions of square miles! Of the enormous sensation it produced over all Europe, as well as of the deep impres-

sion it made upon his own youthful mind, Goethe, then about six years old, has given us a masterly account in his autobiography ("Dichtung und Wahrheit").

"For the first time," says the illustrious poet, "the boy's peace of mind was disturbed by an extraordinary event. On November 1, 1755, the earthquake of Lisbon took place, and spread consternation over a world which had long been accustomed to tranquillity and peace. A large and splendid capital, the seat of wealth and commerce, suddenly falls a prey to the most terrible disaster. The earth shakes, the sea rises, ships are dashed against each other, houses, churches, and towers fall in; the king's palace is partly engulphed by the waves; the bursting earth seems to vomit flames, for smoke and fire appear everywhere among the ruins. Sixty thousand persons, but a moment before in the enjoyment of a comfortable existence, are swept away, and they are the most fortunate who no longer feel or remember their misery. The flames continue to rage, along with a host of criminals whom the catastrophe has set at liberty. The unfortunate survivors are exposed to robbery, to murder, to every act of violence; and thus on all sides Nature replaces law by the reign of unfettered anarchy. Swifter than the news could travel, the effects of the earthquake had already spread over a wide extent of land; in many places slighter commotions had been felt; mineral springs had suddenly ceased to flow; and all these circumstances increased the general alarm when the terrible details of the catastrophe became known. The pious were now not sparing of moral reflections, the philosophers of consolations, the clergy of admonitions. Thus the attention of the world was for some time concentrated upon this single topic, and the public, excited by the misfortunes of strangers, began to feel an increasing anxiety for its personal safety, as from all sides intelligence came pouring in of the widely-extended effects of the earthquake. The demon of fear has indeed, perhaps, never spread terror so rapidly and so powerfully over the earth. The boy who heard the subject frequently discussed

was not a little perplexed. God, the Creator and Preserver of Heaven and Earth, whom the first article of faith represented as supremely wise and merciful, appeared by no means paternal while thus enveloping the just and the unjust in indiscriminate ruin. It was in vain that his youthful mind endeavoured to shake off these impressions; nor can this be wondered at, as even the wise and the learned did not agree in their opinions on the subject."

CHAPTER XI.

LANDSLIPS.

Igneous and aqueous causes of landslips—Fall of the Diablerets in 1714 and 1749—Escape of a peasant from his living tomb—Vitaliano Donati on the fall of a mountain near Sallenches—The destruction of Goldau in 1806—Wonderful preservation of a child—Burial of Valleja and Tauretunum, of Plürs and Scilano—Landslip near Axmouth in Dorsetshire—Falling in of cavern-roofs—Dollinas and Jamas in Carniola and Dalmatia—Bursting of bogs—Crateriform hollows in the Eifel.

LANDSLIPS, or sudden subsidences and displacements of portions of land, result both from igneous and aqueous causes.

Wherever cavities have been formed beneath the surface of the earth, whether in consequence of volcanic eruptions or by the erosive and dissolving action of subterranean waters, the shock of an earthquake or the mere weight of the superincumbent mass may cause the roof to fall in, or the superficial ground, no longer sustained by its undermined foundations, to slide away and sink to a lower level.

In mountainous regions it frequently occurs that the foundations of a rock, undermined by filtering waters, give way, and that huge masses of stone and earth, now no longer reposing on a solid basis, are precipitated into the valley below. More than once, the slipping or falling in of a mountain has brought death and destruction upon the humble dwellings of the Alpine peasants, and added many

a mournful page to their simple annals. Thus, in the years 1714 and 1749, large beds of stone were detached from the Diablerets, a mountain stock between the cantons of Vaux and Valais, and burying the meadows of Cheville and Leytron under a mound of rubbish 300 feet deep, killed many herds and shepherds.

In the first of these catastrophes, the life of a peasant was preserved in a wonderful manner. An immense block came toppling down close to his châlet, and covered it like a shield, so as to preserve it from being crushed by the falling *débris*, though piled up two hundred feet above it. Thus, immured as it were in a living tomb, the unfortunate man spent miserable weeks and months, subsisting on the stores of cheese hoarded in his hut, without light and air, and in constant fear that the rocks above his head might give way and bury him under their ruins. With all the energy of despair, he endeavoured to find his way out of the mighty mound of rubbish, and at length, after incredible toil, emerged into the open daylight. More like a spectre than a human being, pale and emaciated, with torn clothes, and covered with bruises, he knocked at the door of his house * in the lower valley, where his wife and children, who had already long reckoned him among the dead, were at first terrified at his ghost-like appearance, and called in the village pastor to convince them of his identity, before they ventured to rejoice at his return.

On the road from Sallenches to Servoz, in the Valley of the Arve, well known to all the visitors of Mont Blanc, may be seen the ruins of a high mountain which collapsed in the year 1751, causing so dreadful a crash and raising such clouds of dust that the whole neighbourhood thought the world was at an end. The black dust was taken for

* It is almost superfluous to mention that in the Alps many of the peasants lead a migratory existence. During the summer they ascend, with their herds, into the higher valleys, where they remain, separated from their families, until the first night-frosts force them to return to their homes on a lower level.

smoke; flames had been seen darting about in the murky clouds, and the report spread to Turin that a new Vesuvius had suddenly opened its subterranean furnaces among the highest of the Alpine mountains. The king, alarmed or interested at the news, immediately sent the famous geologist Vitaliano Donati to gather accurate information on the spot. Donati, travelling night and day, with all the eagerness of a zealous naturalist, arrived while the appalling phenomenon was still in full activity.

"The peasants," writes Donati to a friend, "had all fled from the neighbourhood, and did not venture to approach the crashing mountain within a distance of two Italian miles. The country around was covered with dust, which closely resembled ashes, and had been carried by the wind to a distance of five miles. I examined the dust, and found it to consist of pulverised marble. I also attentively observed the smoke, but could see no flames, nor could I perceive a sulphurous smell; the water also of the rivulets and sources showed no trace of sulphurous matter. This convinced me at once than no volcanic eruption was taking place, and penetrating into the cloud of dust which enveloped the mountain, I advanced close to the scene of the commotion. I there saw enormous rocks tumbling piecemeal into an abyss with a dreadful noise, louder than the rolling of thunder or the roar of heavy artillery, and distinctly saw that the smoke was nothing but the dust rising from their fall.

"Further investigations also showed me the cause of the phenomenon, for I found the mountain to consist of horizontal strata, the lowest being composed of a loose stone of a slaty texture, while the upper ones, though of a more compact nature, were rent with numerous crevices. On the back of the mountain were three small lakes, the water of which, penetrating through the fissures of the strata, had gradually loosened their foundations. The snow, which had fallen during the previous winter more abundantly than had ever been known within the memory of man, hastened the progress of destruction, and caused

the fall of six hundred million cubic feet of stone, which alone would have sufficed to form a great mountain. Six shepherds, as many houses, and a great number of cows and goats, have been buried under the ruins.

"In my report to the king I have accurately described the causes and effects of the catastrophe, and foretold its speedy termination—a prediction which has been fully verified by the event—and thus the new volcano has become extinct almost as soon as its formation was announced."

Fortunately, this grand convulsion of nature, which spread consternation far and wide, caused the death of but a few victims. The landslip of the Rufi or Rossberg, which, on September 2, 1806, devastated the lovely Vale of Goldau, and overwhelmed four villages, with their rich pasture-grounds and gardens, was far more disastrous. The preceding years had been unusually wet, the filtering waters had loosened the Nagelflühe, or coarse conglomerate of which the mountain is composed, and the rains having latterly been almost continuous, a great part of the mountain, undermined by the subterranean action of the waters, at length gave way and was hurled into the valley below.

Early in the morning the shepherds who were tending their herds on the mountains perceived fresh crevices in the ground and on the rock-walls. In many parts the turf appeared as if turned up by a ploughshare, and a cracking noise, as if roots were violently snapped asunder, was heard in the neighbouring forest. From hour to hour, the rents, the cracking, the rolling down of single stones increased, until finally, at about five in the afternoon, a large chasm opened in the flanks of the mountain, growing every instant deeper, longer, and broader. Then from the opposite Righi the forest might be seen to wave to and fro like a storm-tossed sea, and the whole flank of the mountain to slide down with a constantly increasing velocity, until finally hundreds of millions of cubic feet of rock came sweeping down into the valley with a noise as

if the foundations of the earth were giving way. The friction or clash of the huge stones, hurled against each other in their fall, produced so intense a heat that flames were seen to flash forth from the avalanche, and the moisture with which they were saturated, being suddenly changed into steam, caused explosions like those from the crater of a volcano. Dense clouds of dust veiled the scene of destruction, and it was not before they slowly rolled away that the whole extent of the disaster became visible. Where, but a few hours since, four prosperous villages—Goldau, Busingen, Upper and Lower Röthen, and Lowerz—had been gilded by the sun, and numerous herds had been grazing on the rich pastures along the borders of the Lake of Lowerz, nothing was now to be seen but a desolate chaos of rocks, beneath which 457 persons lay buried. From this terrible disaster some wonderful escapes are recorded. High on the slope of the Rossberg lived Bläsi Mettler, with his young wife Agatha. When, in the morning, the first premonitory signs of the disaster appeared, and the labouring mountain began to raise its warning voice, the superstitious peasant, fancying he heard the jubilee of demons, hastened down to Arth, on the bank of the Lake of Zug, and begged the parish priest, with tears and lamentations, to accompany him, and exorcise the evil spirits with a copious sprinkling of holy water. While he was still speaking, the catastrophe took place, and he now rushed back again to his hut, where beyond all doubt his beloved wife and his only child, which was but four weeks old, had found a premature grave.

Meanwhile Agatha had spent several anxious hours. She was preparing her humble evening meal when the thundering uproar and the shaking of the hut filled her with the terrors of death. Seizing the infant, which lay awake in its cradle, she crossed the threshold, while the soil under her feet slid down into the valley. Escaping into the open air, she looked back and saw her hut and a sea of huge stone blocks roll down into the vale below, while the spot on

which she stood remained unmoved. In this situation she was found by Bläsi, who, though a poor and ruined man, still thanked God for the wonderful preservation of his family.

About a thousand feet lower down the mountain lived Bläsi's brother Bastian, who, when the mountain slipped, was tending his herd on the opposite Righi. But his wife and her two little children were in his hut when it was buried beneath the stony avalanche. After the terrible commotion had subsided, the relations of Frau Mettler, anxious to ascertain her fate, hastened to the scene of desolation. The hut had disappeared, the green Alpine meadow was covered with a heap of ruins, but, not far from the former site of the humble cottage, the youngest child lay quietly sleeping. At the peril of his life, one of the infant's relations clambered over the ruins and rescued the little sleeper, who, unhurt amidst the falling rafters of the hut and the ruins of the crumbling mountain, had been carried away with the bed on which he was reposing. On my last visit to Switzerland, I was informed that Sebastian Meinhardt Mettler, the child thus wonderfully saved, died in the year 1867, at the age of sixty-one.

Some of the victims who had been buried in the ruins of the villages were dug out and restored to daylight; others, less fortunate, may have slowly perished, immured in a living grave; but by far the greater number were no doubt suddenly killed. The total number of those who were saved, either by the assistance of their friends, or by a timely flight, or by absence from their homes at the time of the disaster, amounted to 220; but more than double that number perished, and probably there was not one among the survivors who had not to lament the loss of friends and kinsfolk.

This dreadful catastrophe also levied its tribute among the strangers whom the beauties of Alpine scenery annually attract to Switzerland. A party of tourists had left Arth in the afternoon, with the intention of spending the night in Schwyz. Part of the company had already entered the

ill-fated village of Goldau, and the others were about to follow, when suddenly the thundering roar of the sliding mountain caused them to stop. Looking up and seeing rocks, forests, huts, all rushing down in horrible confusion, they instinctively ran back for their lives. The warning came not one instant too soon, for close behind the spot where they stopped panting for breath, the stones still fell like hail. But their unfortunate companions, the wife and daughter of Baron Diesbach, Colonel Victor von Steiger, and some boys, whose tutor had been slowly following them with the baron, were buried beneath the ruins.

From the Righi the traveller still looks down upon the avalanche of stones, and the flank of the Rossberg still plainly shows the spot where, more than half a century ago, the masses of rock now reposing in the valley detached themselves from the mountain. But the beautifying hand of vegetation has already done much to adorn the scene of ruin. Green mosses have woven their soft carpet over the naked stones, while grasses and flowers, and in some places even shrubs and trees, have sprung up between them. The tears also which once were shed over the victims of the great catastrophe have long since been dried, and its last witnesses have passed away to make room for a new generation, who remember the mountain-slip which buried their fathers only as a legend of the past.

This terrible disaster, however appalling through the far-spread desolation it entailed, has yet been equalled or surpassed by others of a like nature. In the fifth century, the old Roman town of Velleja was buried under the ruins of the Ravinazzo Mountain, and the bones and coins dug out of its ancient site prove that no time was left to the inhabitants for flight. Tauretunum was once a flourishing Roman town, situated on the south bank of the Lake of Geneva, at the foot of the Dent d'Oche. In 563 it was utterly destroyed by a disruption of the overhanging mountain. The avalanche of stones which at that time was hurled down upon the devoted city is still visible as a promontory

projecting far into the lake, which is here at least 500 feet deep. The immense wave caused by the rocky mass as it plunged into the water inundated the opposite shore from Morges to Vevay, and swept away every homestead that lay on its path.

In the night of September 4, 1618, the falling of the Monte Conto, in the Vale of Chiavenna, so completely buried the small town of Plürs and the village of Scilano, that of their 2430 inhabitants but three remained alive, and but one single house escaped the universal destruction. At present, magnificent chestnut-trees grow upon the mound of ruins, and cast their shade over the graves of the long-forgotten victims. Three villages, with their whole population, were covered in the district of Treviso when the Piz mountain fell in 1772; and the enormous masses of rock which in 1248 detached themselves from Mount Grenier, south of Chambery in Savoy, buried five parishes, including the town and church of Saint André, the ruin occupying an extent of about nine square miles.

Sometimes the same village has been repeatedly destroyed by mountain-slips. Thus excavations have shown that Brienz, a hamlet built on the borders of the lake of the same name, on a mound of accumulated ruins, has been twice overwhelmed by a deluge of stones and mud, and twice reconstructed.

It would be useless to multiply examples of the undermining power of water. I will merely add that it is impossible to wander through the valleys of Switzerland without being struck by the sight of the sloping hillocks of rubbish piled up against the foot of every gigantic rock-wall, which in many cases can only be attributed to that cause. Some are entirely overgrown with large firs, thus showing that the last stony avalanche took place at a remote period; others are desolate heaps of rubbish, which evidently prove that the work of destruction is constantly going on, and that the highest peaks will ultimately be levelled with the plain. Over many a hamlet the sword of Damocles is continually suspended in the shape of a precipitous rock-

wall, or of a forest-crowned mountain-brow. For years the undermining waters are slowly and secretly at work, and then suddenly the crisis takes place.

Were the history of the Andes or of the Himalayas as familiar to us as that of the Alps, we should be able to relate many like instances of disastrous mountain-slips. But the high places of the earth do not alone bear witness to the power of aqueous erosion, for wherever the soil is undermined it may be precipitated to a lower level. Thus the phenomenon is by no means uncommon in England, though rarely occurring on so large a scale as in the landslip which took place at Axmouth in Dorsetshire, on December 24, 1839.

"The tract of downs ranging there along the coast," says Sir Charles Lyell ("Principles of Geology"), "is capped by chalk, which rests on sandstone, beneath which is more than 100 feet of loose sand, the whole of these masses reposing on retentive beds of clay shelving towards the sea. Numerous springs, issuing from the loose sand, have gradually removed portions of it, and thus undermined the superstratum. In 1839, an excessively wet season had saturated all the rocks with moisture, so as to increase the weight of the incumbent mass, from which the support had already been withdrawn by the action of springs. Thus, the superstrata were precipitated into hollows prepared for them, and the adjacent masses of partially undermined rock, to which the motion was communicated, were made to slide down, on a slippery basis of watery sand, towards the sea. These causes gave rise to a convulsion, which began on the morning of December 24, with a crashing noise; and, on the evening of the same day, fissures were seen opening in the ground, and the walls of tenements rending and sinking, until a deep chasm or ravine was formed, extending nearly three-quarters of a mile in length, with a depth of from 100 to 500 feet, and a breadth exceeding 240 feet. At the bottom of this deep gulf lie fragments of the original surface, thrown together in the wildest

confusion. In consequence of lateral movements, the tract intervening between the new fissure and the sea, including the ancient undercliff, was fractured, and the whole line of sea-cliff carried bodily forwards for many yards. This motion of the sea-cliff produced a further effect, which may rank among the most striking phenomena of this catastrophe. The lateral pressure of the

Axmouth Landslip.

descending rocks urged the neighbouring strata, extending beneath the shingle of the shore, by their state of unnatural condensation, to burst upwards in a line parallel to the coast, so that an elevated ridge, more than a mile in length and rising more than forty feet, covered by a confused assemblage of broken strata and immense blocks of rock, invested with seaweed and corallines, and scattered over with shells and starfish, and other productions of the

deep, forms an extended reef in front of the present range of cliffs."

Landslips caused by the falling in of cavern roofs are nowhere more common than in the cretaceous strata, which are more liable than others to be undermined by the action of running waters. In the vast chalk-range extending from Carinthia to the Morea, they occur of all sizes, from a diameter of a few fathoms to one of many thousand feet, and are not seldom of considerable depth. They are generally funnel-shaped, sometimes elongated; and the bottom of the larger ones is generally covered with villages, orchards, vineyards, or considerable tracts of arable land. In Dalmatia, Carinthia, Carniola, and Istria, where the country consists chiefly of arid plateaux or mountain chains, exposed to the dry north-easterly winds, the cultivation of the soil is almost exclusively confined to these depressions or *dollinas*, which, as a further protection against the cutting blasts, are enclosed with walls of loose stones.

Besides the funnel-shaped landslips or *dollinas*, there are others with perpendicular sides like walls or shafts, which are called *jamas* or mouths. One of these (near Breschiak) descends to a depth of 384 feet. The hares seek a winter refuge in the *dollinas*, and the *jamas*, as the favourite resort of pigeons, are also called pigeon-holes or *golubinas*. Many a pedestrian has lost his life by falling into a *jama*, particularly in former times, when fewer precautions were taken to protect the stranger against these treacherous precipices.

In the Jura Mountains there are also whole rows of caldron-shaped depressions; and in North Jutland, where the chalk formation is likewise very extensive, a recent landslip suddenly emptied the Norr Lake, which lost itself in subterranean channels.

Effects very similar to those of an ordinary landslip are sometimes produced by the bursting of a bog. On the western confines of England and Scotland, the Solway Moss occupies a flat area about seven miles in circum-

ference. Its surface is covered with grass and rushes, presenting a dry crust and a fair appearance; but it shakes under the least pressure, the bottom being unsound and semi-fluid. The adventurous passenger, therefore, who sometimes, in dry seasons, traverses this treacherous waste, must pick his way over the rushy tussocks as they appear before him, for here the soil is firmest. If his foot slip, or if he venture to move in any other part, it is possible he may sink never to rise again.

On December 16, 1772, this quagmire, having been filled, like a great sponge, with water, during heavy rains, swelled to an unusual height above the surrounding country, and then burst. The turfy covering seemed for a time to act like the skin of a bladder retaining the fluid within, till it forced a passage for itself, when a stream of black half-consolidated mud began at first to creep over the plain, resembling in the slow rate of its progress an ordinary lava-current. No lives were lost, but the deluge totally overwhelmed some cottages, and covered 400 acres with a mass of mud and vegetable matter, which in the lowest parts of the submerged area was at least fifteen feet deep.

It may easily be imagined, that in Ireland, the classical land of bogs, such phenomena are not uncommon. In the peat of Donegal an ancient log-cabin was found, in 1833, at the depth of fourteen feet. The cabin was filled with peat, and was surrounded by other huts, which were not examined. Trunks and roots of trees, preserved in their natural position, lay around these huts. There can be little doubt that we have here one instance out of many in which villages have been overwhelmed by the bursting of a moss.

In many volcanic regions we find circular caldron-shaped depressions in the earth's surface, which might easily be mistaken for landslips, but which have in reality been formed by explosive discharges of confined vapours. When vents or fissures are produced by a paroxysm of volcanic energy, we can easily understand how in some

cases the pent-up gases, finding a sudden outlet through some weaker part of the surface, must act like a powder mine, and scattering the rocks that surrounded the orifice, leave a deep hollow behind as a memento of their fury. The depressions thus caused bear a great resemblance to real craters, from which they are, however, distinguished by the absence of a cone of scoriæ and from their never having ejected lava.

These curious crateriform hollows are very common in the Eifel, a volcanic region in Rhenish Prussia, where, probably owing to the clayey nature of the soil, they have become reservoirs of water, or Maare, as they are called by the natives. Most of them still have small lakes at their bottom, while others have been drained for the sake of cultivation, or by the spontaneous rupture or erosion of their banks. Some of them are of considerable dimensions, such as that of Meerfeld, the diameter of which falls very little short of a mile; or the Pulvermaar of Gillenfeld, remarkable for the extreme regularity of its magnificent oval basin.

Similar lakes or Maare occur in Auvergne, in Java, in the Canary Islands, in New Zealand, and in the volcanic districts of Italy. The beautiful lakes of Albano and Nemi, which have been so often sung by ancient and modern poets, belong to this class; but Fr. Hoffman, a celebrated German geologist, ascribes the origin of the former to a landslip caused by the falling in of the roof of a vast subterranean cavern.

THE END.

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